JOURNAL OF THE A·I·E·E·

JANUARY — 1927

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

WINTER CONVENTION, New York, N. Y., February 7-11

SUMMER CONVENTION, Detroit, Mich., June 20-24

PACIFIC COAST CONVENTION, Del Monte, Calif., September 13-16

REGIONAL MEETINGS

South West District No. 7, Kansas City, Mo., March 17-18
Middle Eastern District No. 2, Bethlehem, Pa., April 14-16
Northeastern District No. 1, Pittsfield, Mass., May 25-27

MEETINGS OF OTHER SOCIETIES

Empire State Gas and Electric Association, Electric Section Edison Auditorium, 44 West 27th St., New York, N. Y., Jan. 14-15

American Society of Civil Engineers, Engineering Societies Building, New York, N. Y., January 19-21

The American Physical Society, New York, N. Y., Feb. 26; Washington, April 22-23

JOURNAL

OF THE

American Institute of Electrical Engineers

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33 West 39th Street, New York

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines, $10.50 to Canada and $11.00 to all other Countries. Single copies $1.00.

Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

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Printed in U. S. A.

Current Electrical Articles Published by Other Societies

Iron & Steel Engineer, November 1926

Lightning Arrester Design and Research, by H. M. Towne
Maintenance of Electric Motors, by H. L. Rea
Renewal Parts and Renewal Part Records, by W. S. Shirk
Electrical Hazards in the Steel Industry, by F. W. Cramer

National Electric Light Assn. Bulletin, November 1926

Outlook for the Manufacturer of Electrical Apparatus and Supplies, by M. H. Aylesworth
Rural Electrification in Alabama
Where Oregon Stands with Farm Electrification

Proceedings of Institute of Radio Engineers, December 1926

Notes on the Design of Resistance-Capacity Coupled Amplifiers, by S. Harris
Output Characteristics of Amplifier Tubes, by J. C. Warner and A. V. Loughren
Radio Signal Strength and Temperature, by L. W. Austin and I. J. Wymore
Simultaneous Atmospheric Disturbances in Radio Telegraphy, by M. Baumer

Society of Naval Architects & Marine Engineers, November 1926

Performance Tests on Diesel Electric Stern Wheel Towboats, by C. H. Giroux
Diesel Electric Propulsion, by W. E. Thau

Transactions, Amer. Society Steel Treat., November 1926

Electric Annealing of Magnetic Materials for Telephone Apparatus, by W. A. Timm

Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLVI JANUARY, 1927 Number 1

The A. I. E. E. Technical Committee on Electrical Machinery

The Technical Committee on Electrical Machinery was appointed in 1917 by Mr. E. W. Rice who was then President of the Institute. It comprised six members. The late Professor Alexander M. Gray was Chairman. Its first annual report is given at p. 720 of Vol. XXXVII (1918) of the TRANSACTIONS. The concluding paragraph of this first report is of such interest that it is given below:

"While the chief function of the technical committees is to secure papers in their respective fields, the Committee on Electrical Machinery considers that it might well be used as a clearing house for suggested changes to the Standardization Rules, a place where suggestions dealing with machinery might be thoroughly thrashed out before being submitted to the Standards Committee."

At an earlier place in the report we read:

"We believe that one of the principal functions of the technical committees is to keep the literature of their subject in good shape."

In the course of the report suggestions are made to the Educational Committee as to some educational needs concerning electrical machinery.

Attention is called to these matters to suggest that already in this first report of the Electrical Machinery Committee, its six members recognized that it ought to deal with (1) Papers (2) Standards and (3) Education.

The Electrical Machinery Committee under the administration of Professor Gray, its first Chairman, and Mr. B. A. Behrend, his successor, rapidly extended its activities. It has at present forty members. Five are professors of electrical engineering. Twenty-two are associated with ten different manufacturers of electrical machinery and thirteen with users thereof. The Committee organization comprises subcommittees on (1) Standards (2) Papers (3) Research and (4) Education.

(1) *Standards.* The Standards subcommittee of which Mr. E. C. Stone is Chairman, is carrying out much very important standardization work and has several subcommittees. Its work when completed is submitted to the Institute Standards Committee for approval and coordination. When found acceptable by the Standards Committee the Standards are then sent by that committee to the A. I. E. E. Board of Directors for approval as Institute Standards.

(2) *Papers.* Dozens of papers on electrical machinery are received by and presented in the Institute in the course of every year. Each of these is reviewed by one or more members of the Committee on Electrical Machinery to determine its suitability for presentation in the Institute. Suggestions for papers to meet the developments in and needs of the industry are often brought to the committee.

In recent years an important task of the committee has been the preparation of a report on the year's progress in the art for presentation at the Annual Convention. Valuable reports were prepared in 1925 and 1926 respectively, under the direction of Mr. J. C. Parker (assisted by Mr. J. A. Brooks) and Mr. B. L. Barns. Mr. Barns, with the collaboration of the entire committee, is preparing this year's report.

(3) *Research.* The Institute appropriates no funds for research, but its recommendations regarding various research problems are of use to other organizations. Moreover Institute members in industrial and college laboratories are often in a position to promote needed research investigations. Prof. Karapetoff, who is a member of the Institute's Research Committee is Chairman of the Electrical Machinery Committee's subcommittee on research.

The committee's experience indicates that most of the work relating to research should be done in subcommittees, this work being reviewed by the main committee on the occasions of the four or five meetings which it should hold in the course of each year. It is believed that these subcommittees should be small, the members of any one committee preferably being in one locality so that frequent meetings may be held and steady progress made without too great expense and consumption of time in traveling. Before the final adoption of any conclusions from the work of such regional committees, wide publicity should be given to their reports through the JOURNAL or otherwise, with a view to re-submitting to the committee the comments and criticisms and suggestions thus obtained.

Some of the research subjects which can profitably be studied are of a kind which can be assigned to groups of students under the general direction of their professor.

(4) *Education.* The education subcommittee is under the Chairmanship of Prof. C. A. Adams who is also a member of the Institute's Committee on Education. This ties in the subject of education with the Institute's organization in the same way in which the subjects of standardization, papers and research are tied in with three other Institute coordinating committees.

In Conclusion. Although the manufacture of electrical machinery had already acquired considerable headway forty years ago, the rate of growth in quantity, in size, in variety and in improved quality is greater at

present than ever before and there is no indication of any approach to the saturation point for the work of this Committee.

Thus, there awaits the attention of the Electrical Machinery Committee a practically limitless amount of work. The committee will be very glad to hear from any individual or group in any locality, who will offer to serve as a regional subcommittee and accept an assignment. It is not necessary that the individual or the members of the group be members of the committee. Members of the Institute wishing to participate to a greater extent in its useful and particularly arduous activities and not knowing just how to go about the matter are cordially invited to write to Mr. E. B. Paxton, the Secretary of the Electrical Machinery Committee, or to the Chairman.

HENRY M. HOBART, Chairman
Committee on Electrical Machinery.

Some Leaders of the A. I. E. E.

Frank Baldwin Jewett, the thirty-fifth President of the Institute, 1922-1923, was born in Pasadena, California, September 5, 1879. He graduated from Throop Polytechnic Institute, Pasadena, (now California Institute of Technology) in 1898 and took a postgraduate course at the University of Chicago, where he obtained his degree of Ph. D. in 1902. After serving one year as research assistant to Professor A. A. Michelson of the University of Chicago, he became Instructor in Physics and Electrical Engineering at the Massachusetts Institute of Technology. In 1904, he entered the employ of the American Bell Telephone Company in Boston and was transferred to New York in 1907 when the engineering activities of the Bell System were consolidated.

Doctor Jewett entered the telephone field at a time when that industry was on the threshold of a great expansion and the value of scientific research was just beginning to be appreciated. He brought to the telephone industry, a mind trained in scientific procedure and a contagious enthusiasm for surmounting difficulties.

In 1912, Doctor Jewett was appointed assistant chief engineer of the Western Electric Company, becoming chief engineer in 1916.

When the United States entered the War in 1917, Doctor Jewett had already been commissioned as Major in the Signal Corps and was ready to be called into active service. For the duration of the War his efforts were directed almost entirely to the solution of problems connected with the national defense and the development and supply of adequate communication equipment to the American Expeditionary Forces. He also assisted the Navy Department as a member of the Special Board to Consider and Experiment with Submarine Devices and was a member of the State Department's Committee on Submarine Cables. He was promoted to the rank of Lieutenant-Colonel in 1918, and in 1919, was awarded the Distinguished Service Medal for exceptionally meritorious service.

In April, 1921, Doctor Jewett became vice-president and chief engineer of the Western Electric Company, and in 1922, vice-president in charge of manufacturing, engineering, installation and telephone distribution; also vice-president of the International Western Electric Company. At the end of 1924 he relinquished these posts to become vice-president of the American Telephone and Telegraph Company and president of the Bell Telephone Laboratories, Inc.

During Doctor Jewett's association with the Western Electric Company, many of the most important advances in the field of communications were made. These included development of the vacuum tube, improvements in the art of inductive loading, building of the transcontinental telephone line, development of the telephone repeater, the first transatlantic radio telephone communication, introduction of machine switching on a large scale by the Bell System, and the development of a high-speed submarine telegraph cable. As an engineer, Doctor Jewett has had a large share in all of these developments.

He is a member of the National Academy of Sciences and chairman of the Division of Engineering and Industrial Research, National Research Council. He is identified with numerous scientific and educational institutions and has received honorary degrees both from New York University and from Dartmouth College. He is a man keenly interested in outdoor sports and has been admitted to membership in numerous clubs and societies. Doctor Jewett is a member of the Board of Education in his home town and takes an active part in civic affairs generally. He is the author of many papers dealing with scientific subjects and has received the Order of the Rising Sun from the Emperor of Japan in recognition of valuable services.

As vice-president of the American Telephone and Telegraph Company in charge of development and research, and as president of the Bell Telephone Laboratories, Inc., Doctor Jewett now occupies a position of far-reaching importance.

Development in Standardization

Notable developments in the industrial standardization movement have been achieved during 1926, according to an announcement of the American Engineering Standards Committee.

Instead of leaving their standardization work as a more or less incidental function industrial executives are more and more providing a definite organization for their standardization work. The systematic organization of company standardization work is leading to a much larger degree of cooperation between companies. For example, more than thirty Cleveland firms have reorganized their screw thread practise in accordance with the revised national standard, and more than a dozen firms have systematized their entire control of interchangeable manufacture through the introduction of the new national standard of limit gaging.

Frequency Measurements with the Cathode Ray Oscillograph

BY FREDERICK J. RASMUSSEN*

Non-member

Synopsis.—The cathode ray oscillograph frequency measurement circuit described differs from previous circuits in the use of by-pass condensers and plate leaks which permit the connection of the oscillograph to a-c. circuits having large d-c. components and which permit the use of biasing controls for shifting the position of patterns on the screen.

Reference oscillators are used in conjunction with the frequency standards. They are of a type chosen for their high stability.

The well-known properties of Lissajous' figures are reviewed briefly and then developed more fully for the cases in which only one term of their ratios may be determined from the oscillograph pattern. Following a general discussion of the accuracy of syntonization, there is discussed a detailed method of calibrating oscillators. The patterns used may be interpreted from one term of their ratio.

Interpolation formulas are derived for use in making interpolations on the reference oscillators. The methods of interpolaion, discussed may be used for intervals up to 0.5 per cent frequetncy with high degrees of accuracy.

The interpolation formulas are extended further in the development of approximation methods by which any unknown frequency may be quickly determined within a few per cent.

Several special circuits are described for use in frequency measurement work with the cathode ray oscillograph.

The methods and apparatus described are suitable not only for the technical measurements of a development and research nature but are equally adaptable for routine commercial work. The advantages which particularly commend themselves are the rapidity with which such work may be done and the ease with which the average man can learn the work.

With the advance of the telephone and radio broadcasting art and the advent of the radio telephone, the need for more precise measurement and control of the frequency of alternating-current potentials has been increasing. In practise, the accuracy requirements of frequency meters and other frequency measuring devices have become more severe. In the laboratory, rapid and accurate methods of calibrating field standards of frequency, laboratory oscillators and tuning forks are demanded. Resonance methods of measuring electrical constants are applicable only in proportion to the availability and accuracy of frequency measurements. The study of small frequency variations due to extraneous causes is largely dependent upon the relative accuracy of measurements made at infrequent intervals. To meet these needs, J. W. Horton, N. H. Ricker and W. A. Marrison[1] developed a continuously operated, 100-cycle tuning fork from which a source of alternating current is supplied. This system has proved to be an extremely accurate and constant source of frequency. The rate of the 100-cycle fork is maintained to 1 part in 100,000 at all times, and its deviation from 100 cycles may be maintained constant and known to an accuracy considerably better than this. At the same time, circuits were developed for producing and separating the harmonics of the base frequency. By means of these circuits there are produced 1000-cycle and 10,000-cycle sources of alternating current which have the same percentage accuracy as the 100-cycle standard, and may be used when it is desirable to have a higher frequency standard.

Coincidently with the adoption of the above sources of alternating currents as the laboratory standards of frequency, the development of the low-voltage cathode ray oscillograph[2] was completed, and there became available for general laboratory use accurate methods of frequency measurement by means of these two new tools, the extremely accurate source of standard frequencies and a commercial low-voltage cathode ray oscillograph.

The telephone industry uses a very large number of vacuum tube and other types of oscillators. The maintenance of oscillator calibrations in the laboratories and the calibration of field equipment furnish a very considerable amount of frequency measurement work. To take care of this work, frequency calibration has been largely centralized. It is the purpose of this paper to describe a special frequency measurement equipment and the methods of using it. The equipment was designed especially for use in the routine calibration of oscillators, tuning forks, wavemeters and all electrical circuits in which a frequency adjustment or measurement is required. It was also designed for precision measurements incidental to many present developments and necessary in the maintenance of frequency substandards of all kinds. Those parts of the equipment which are used in connection with a large part of the work have been installed as a unit; those which are used less frequently have been assembled as portable units which are installed only during use.

The general principles of the circuits and the methods used are in some cases the same or similar to those described in the literature already available on this subject, and the liberty will be taken of including such matter here with references to familiar papers but without attempting to determine original publications.

A schematic diagram of the frequency measuring apparatus is given in Fig. 1. Essentially, it consists of the sources of standard frequency, potentiometers for controlling the output of the standards, two stable

*Bell Telephone Laboratories, Inc., New York, N. Y.

[1]For references see end of paper.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

vacuum tube oscillators, and the cathode ray tube oscillograph with a multiplicity of input terminals for placing frequencies on the oscillograph at will. The alternating-current potentials are applied to either the horizontal or vertical plates of the oscillograph by means of a number of low-capacity, single-pole, double-throw switches. Rather than connect the input frequencies

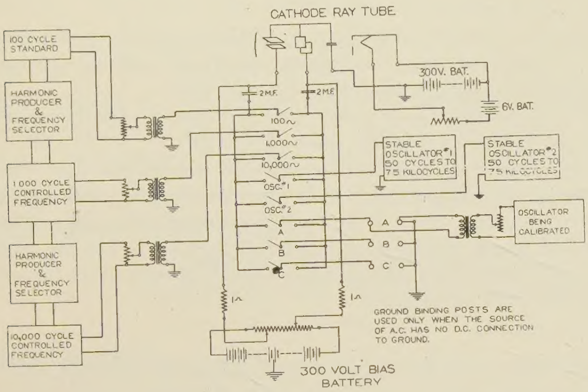

Fig. 1

of the oscillograph directly to the plates, they are coupled to the plates through two-microfarad by-pass condensers and a plate leak is added to furnish the correct d-c. potential. This means is used, as it makes the d-c. components of the oscillograph and the source independent. A typical example of its usefulness is in measurements on a circuit where the most available position having a sufficient a-c. potential is at the plate of a vacuum tube. The diagram shows the plate leak going to a potentiometer shunting a 300-volt battery with a grounded center. For most work it is necessary only to have the leak go to ground, in which case the figure on the oscillograph will place itself centrally on the screen. The purpose of the potentiometer is to add to the a-c. potential a d-c. potential which will change the figure's position on the screen.

The vacuum tube oscillators form an important part of the equipment. They are stable oscillators of a type similar to those described by J. W. Horton[3] and are constructed so that under laboratory conditions of constant battery supply and uniform temperature they will maintain a frequency setting to ± 0.01 per cent for long periods of time. The oscillating coils are of the air core toroidal type. The frequency is controlled by changing the oscillating coils and adjusting the associated tuning capacity. The tuning condensers are mica condensers arranged in decade followed by an air condenser, and are calibrated carefully to facilitate interpolation. In order that the frequency settings may be read with a relative precision comparable to the accuracy provided by the frequency standards, the inductance and the number of oscillating coils have been so chosen that any frequency from 35 cycles to 75,000 cycles may be obtained with a capacity setting of not less than 0.015 μf. The air condensers are of a type which may be read in increments per scale division of 0.6 $\mu\mu f$. and 1.0 $\mu\mu f$. respectively, which permit reading settings at 0.015 μf. in increments of ± 0.001 per cent and ± 0.002 per cent frequency respectively. In order to furnish any desired voltage range for the oscillograph inputs, the oscillator outputs are provided with switching arrangements associated with output transformers of various turn ratios.

Although not a permanent part of the equipment, two oscillators having frequency ranges up to 350 and 1500 kilocycles, respectively, are available.

The Use of the Cathode Ray Oscillograph

The cathode ray oscillograph which forms the nucleus of the frequency measurement equipment has for its main purpose the syntonization of alternating potentials. Its usefulness depends upon its property of creating figures of various designs when syntonized frequencies are applied to its plates. Within the limitations of the cathode ray tube used, a figure of some kind always results if two frequencies which are not incommensurate are applied to its plates, the complexity of the figure being less, the more simple the ratio between frequencies.

LISSAJOUS FIGURES

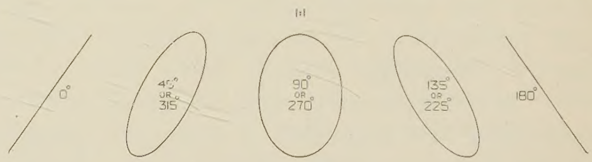

Fig. 2

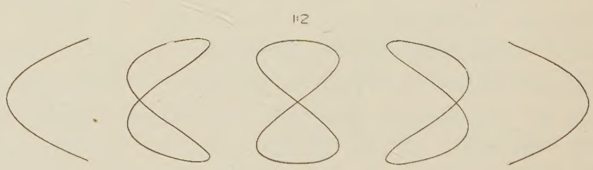

Fig. 3

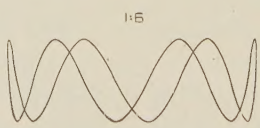

Fig. 4

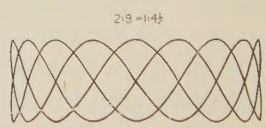

Fig. 5

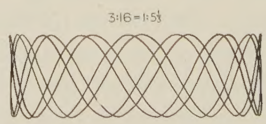

Fig. 6

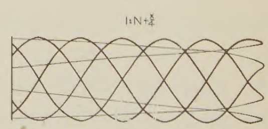
Fig. 7

Illustrations of typical and useful figures are given in Figs. 2 to 13. When two sinusoidal alternating potentials having the same frequency are applied to the plates of the cathode ray oscillograph, a straight line is obtained if the phase relation between the potentials

is 0 deg. or 180 deg. At other phase relations, an ellipse results, the slope of whose axis depends on the phase relation. This is illustrated by Fig. 2. Fig. 3 shows the figure resulting with various phase relations when the frequency ratio is 2 to 1, and Fig. 4 shows the figure resulting from a ratio of 1 to 6. If these figures are observed on the cathode ray oscillograph when the ratio is not quite commensurate, the figure proceeds from one phase to the next. The movement of the figure makes it appear as if a picture of the higher frequency wave were drawn on a transparent revolving cylinder with its axis in the plane of the oscillograph screen. In the case of a simple ratio of one to an integral number, the ratio may be readily determined by counting the number of waves which appear to be described around the cylinder. Also it is not difficult to determine somewhat more complex ratios as those illustrated

LISSAJOUS FIGURES

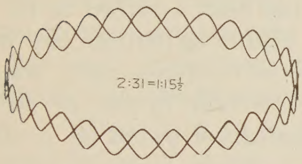

Fig. 8

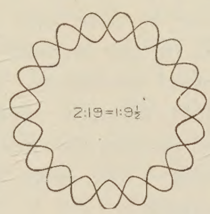

Fig. 9

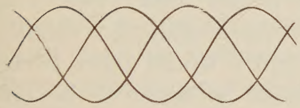

Fig. 10

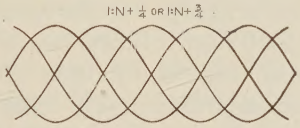

Fig. 11

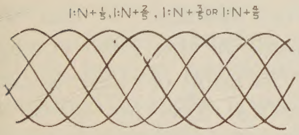

Fig. 12

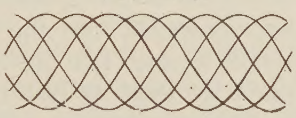

Fig. 13

in Figs. 5 and 6. When the patterns become more complex than those illustrated, it becomes correspondingly more difficult to determine their ratios. Consequently means are devised to avoid the necessity of actually counting the waves of a pattern to determine frequency ratios.

By various means, it is possible to place the figure upon the oscillograph in such a manner that, referring to the transparent cylinder illusion, the back part of the figure is readily distinguished from that of the front, or in such a manner that one part is absent entirely[4, 5]. In the first case, figures similar to that shown in Fig. 7 are obtained; in the second those similar to Figs. 8 to 13. Figs. 10 to 13 are the same as Fig. 8 but are obtained by the use of large a-c. potentials so biased as to bring the desired portion on the screen.

In general calibration work, methods employed are such that only the numerator in the lowest term ratio of the lower frequency to the higher is used. The numerator is spoken of as the number of lines in the figure. Thus, Figs. 2, 3 and 4 show one-line figures. The lowest term ratio in all cases is one to an integer. The illustrations in Figs. 5, 8 and 9 are spoken of as two-line figures. Their ratio is two to an integer and may all be reduced to one over an integer plus one-half. Figs. 6 and 10 are spoken of as three-line figures. Their ratios are one to some integer plus ⅓ or ⅔. Thus, if we can count the number of lines, vertical or horizontal, in a given figure we know that the ratio is

$1:\left(N + \dfrac{X}{l}\right)$, where N is an unknown integral, l the number of lines counted, and X an integer less than l and not having a factor common to l.

Except for the limitations explained below, it has been found practical with the 100-cycle standard to use figures containing up to 12 lines at audio frequencies, and up to 5 lines through the carrier range. At radio frequencies, it is difficult to use the 100-cycle standard and it usually is not practicable. Against other standards, however, four- and five-line figures are used in this range. In the carrier range, up to 15-line figures have been tried successfully at ratios of over 1:10.

In order to facilitate the use of the more complex ratios, Table I was prepared for use with the 100-cycle standard, but may be used readily with other frequencies. It contains a column giving in order the decimal value times 100 of every fraction down to twelfths, and another giving the denominator of these fractions. An example of its use follows:

Assume that it is desired to set an oscillator at a frequency of 6015 cycles and that the oscillator calibration gives 6000 and 6200 cycles. The frequency, of course, lies between these two points. The 6000 cycle is readily located from the 100-cycle standard by the simple one-line figure. The capacity is now slowly decreased until a figure containing seven lines is obtained. This frequency will be 6000 cycles plus the value 14.29 given in Table I for the seven-line figure next below the one-line figure. Decrease the capacity further and there will obtain a six-line figure, indicating a frequency of 6016.67 cycles. Either of these two frequencies is within 0.05 per cent of the desired frequency. By linear interpolation the desired point may readily be referred to the 100-cycle standard with an accuracy depending on the capacity increment and stability of the oscillator, and the stability of the standard.

The above method can be used universally for obtaining frequencies to 0.01 per cent. If the frequency to be obtained is low, the 100-cycle standard or as low as a 20-cycle frequency may be used. If the frequency is higher, a 1000-cycle standard may be used. As the frequency to be adjusted increases, the number of lines

which may be used decreases, but the per cent increment at which observable lines occur may readily be kept below 0.2 per cent above four kilocycles. At frequencies below 500 cycles, syntonization against a multiple frequency adjusted as above is more often the best method.

The apparatus described naturally has its frequency limitations. In general, due to the necessity of holding the higher frequency in syntonization with the lower-frequency oscillator to within a few cycles, the upper frequency limit is fixed by the type of high-frequency source being used. However, using extremely stable oscillators, calibration work has been done to well over two million cycles. At the low-frequency end of the scale the frequency is limited by the ratio of frequencies, the retention of screen fluorescence, and the size of figure. In precision work where relatively large figures are used it is necessary that the beam trace the entire figure ten times per second and if much work is to be done an even higher rate should be used as the flickering of the picture becomes quite tiring. Thus, syntonizing 85 cycles against 40 cycles, a ratio of 1 : 2 + 1/8 would be undesirable as the pattern is retraced only five times per second. In work of relatively low precision, where small figures are used, retracing the picture five times per second is often quite satisfactory.

TABLE I

DECIMAL TABLE FOR USE IN FREQUENCY CALIBRATION WORK ON THE CATHODE RAY OSCILLOGRAPH

Number of lines	$f - N(100)$	Number of lines	$f - N(100)$	Number of lines	$f - (100)$
1	00.000	11	36.364	10	70.000
12	08.333	8	37.500	7	71.428
11	09.091	5	40.000	11	72.727
10	10.000	12	41.667	4	75.000
9	11.111	7	42.857	9	77.778
8	12.500	9	44.444	5	80.000
7	14.286	11	45.455	11	81.818
6	16.667	2	50.000	6	83.333
11	18.182	11	54.545	7	85.714
5	20.000	9	55.555	8	87.500
9	22.222	7	57.143	9	88.889
4	25.000	12	58.333	10	90.000
11	27.273	5	60.000	11	90.909
7	28.572	8	62.500	12	91.667
10	30.000	11	63.636	1	100.000
3	33.000	3	66.667		

f = frequency observed against 100-cycle standard.
N = any integral.

To use the chart with the 1000-cycle standard, multiply the second column by 10 and change $f - N(100)$ to $f - N(1000)$.

To use with the 10,000 cycle standard multiply by 100 and change to $f - N(10{,}000)$.

Accuracy of Syntonization on the Cathode Ray Oscillograph

The accuracy of syntonization is dependent upon the observation of motion or lack of motion in the figure produced on the screen of the oscillograph. This accuracy for any observation may be checked by watching the figure for a measured period to determine the rate of motion. The best method in routine work of obtaining the required accuracy, however, is to so proportion the potentials that when the figures appear to be standing still the required precision has been attained. For the purpose of this discussion, it is assumed that a spot of light 20 in. from the observer's eyes, moving at a rate of 0.05 in. per second on a blank surface, readily appears to be in motion when observed for only a short interval. Actually, and particularly when a reference mark is used, much slower rates are observed as motion.

Assume that the 100-cycle standard, placed horizontally, is to be used for a series of measurements and that its amplitude is adjusted to make the length from wave to wave of 1000 cycles, placed vertically, one in. Assume further that the approach to syntonization of the two frequencies is such that the waves pass a given reference point at the rate of one per second. It may be shown that the frequency is 999 cycles or 1001 cycles, whence the error in setting the 1000 cycles is ± 0.1 per cent. The rate of motion of the 1000-cycle wave is then one in. per second. If the rate were 0.05 in. per second, which has been assumed to be the slowest movement readily visible as motion, one wave per 20 seconds would pass the reference mark whence the frequency would be 1000.05 cycles or 999.95 cycles. The error of syntonization would be ± 0.005 per cent.

In the preceding discussion one point is left out of consideration; namely, the amplitude of the 1000-cycle figure. If the amplitude of the 1000 cycles is so small that it is practically indistinguishable, it is readily seen that the motion of the figure would have to be considerably faster than assumed in order to be observed. If the amplitude is very large, the lines at the point of observation appear vertical and their motion across the screen is observed very readily. It can be seen, however, that the magnitude of the 1000 cycles should be such that the lines at the point of observation move at least as fast in a vertical direction as in a horizontal direction. Therefore, the slope of the wave at 0 should be 45 deg. or more. This condition exists for a sine wave with a period of one in., when the amplitude is approximately 1/2 in. Practically, it is most natural to adjust the high frequency input to the oscillograph to meet this condition. However, it could be checked easily by balancing the frequency against 10,000 cycles and adjusting its input to make the waves of the 10,000 cycles have a 0.1-in. period.

If an accuracy of ± 0.001 per cent instead of ± 0.005 per cent is desired, the amplitude of the 100 cycles should be five times as great. If a precision of only better than ± 0.01 per cent is desired, the figures need be only half as large.

It is very seldom that syntonization is required to an accuracy of better than ± 0.001 per cent. Due to the width of focus, it is necessary to adjust frequency inputs of over 100,000 cycles to give inputs larger than required for this accuracy. Therefore, very little

thought of the accuracy of syntonization is necessary when one of the frequencies is larger than 100,000 cycles.

As the frequency values decrease, however, the relation between the amplitude of the figure and the accuracy required for instantaneous readings becomes very important. A simple rule which is used to check the amplitude of the lower frequency used in a measurement follows: When the final observation of a reading requiring syntonization to an accuracy of $\pm$ 0.001 per cent is being taken, the amplitude of the lower frequency shall be such that a 100,000-cycle or higher frequency, having an amplitude of 0.1 in., may readily form a distinct figure with it; for $\pm$ 0.01 per cent, 10,000 cycles should be used; for $\pm$ 0.1 per cent, 1000 cycles.

Calibration of Oscillators

The method of calibrating an oscillator necessarily varies in accordance with the type of oscillator, the frequency range, the frequency intervals at which the calibrated points are desired, the accuracy and the relative accuracy required. Oscillators in which the accuracy requirements vary from $\pm$ 10 per cent to $\pm$ 0.1 per cent have been calibrated. On the same oscillators the relative accuracy required has varied from $\pm$ 10 per cent to $\pm$ 0.01 per cent, the relative accuracy being, of course, a measure of the accuracy of frequency differences which are obtainable between various frequency settings. The type of oscillators for which this calibration equipment is particularly designed is that in which the frequency is continuously variable between a lower and an upper limit. To provide for the various ranges there is usually a coil switch for interchanging the coils of the oscillating circuit and for changing the circuit constants to provide the necessary variations in regenerative coupling and for controlling, on some of the older oscillators, filters for the purification of wave form. Oscillators designed to make measurements throughout the audio frequency range are continuously variable between 50 or 100 cycles and 3000 or 5000 cycles, and their calibration charts call for some 150 frequency points. Another common type is that designed for use in both the audio and carrier frequency ranges. Their frequency is continuously variable from 100 cycles to 50,000 cycles. Their calibrations call for almost 500 frequencies. In order to maintain the required accuracies on these oscillators, it is necessary to calibrate them, in most cases, once every year. Obviously, with so many points on the calibration, it is desirable to provide a very rapid means of calibration. The cathode ray oscillograph method permits the calibration of the first oscillator described to be made by two men in but little over one hour and that of the second in about three or four hours.

In most instances of routine calibration work, the approximate calibration is known from the constants of the frequency-control unit or from the fact that it is recalibration work in which the last previous calibration is available. On most oscillators, decade systems of condenser dials are used which permit reading capacity directly to accuracies of the order of $\pm$ 1 per cent, which permits making interpolation calculations over considerable ranges to accuracies approaching $\pm$ 0.5 per cent frequency. This of course forms another considerable aid in the calibration work.

To make the calibration, the oscillator is connected to the required source of direct-current supply and the output to one of the input switches of the oscillograph. If the voltage of the oscillator output is not suitable for calibration work on the oscillograph, it is adjusted by means of a step-up transformer, or by means of a resistance network, if the case requires a stepping down of voltage. If the approximate settings of the oscillator are not known, the lowest frequency of a coil position is determined by an approximation method which is given below. From this, the approximate settings of the first frequency required may be calculated from the relation that the capacity of the oscillator setting varies inversely as the square of the frequency, or if the interpolation is less than say 10 per cent frequency, from the more approximate relation that the relative capacity increase equals twice the relative frequency decrease.

Having determined thus the first point, one of the reference oscillators is adjusted against the frequency standard to four times the arithmetic interval of frequency. The second is set at 10 or 20 times the arithmetic frequency interval. The amplitudes of these oscillators and of the oscillator being calibrated are adjusted to give the required precision. To give a clearer conception of the procedure from this point, a definite example will be given.

The oscillator is to be calibrated from 2000 cycles up, in 50-cycle steps. The first reference oscillator is adjusted to 200 cycles. The second is adjusted to 500 cycles. When 2000 cycles is placed against either of these frequencies a one line figure is obtained. Having adjusted the 2000 cycles with the required precision and recorded its setting, the oscillator being calibrated is set at approximately 2050 cycles by reducing the capacity setting 5 per cent, which is twice 2½ per cent the relative frequency interval at this point*. The air condenser is varied until a four-line figure against the first oscillator appears on the screen. This is adjusted with the required precision. The next point is located in a similar manner, but by the use of a two-line figure; the next by a four-line figure and the next by a one-line figure. When the calibration has proceeded to 2500 cycles, the oscillator being calibrated is checked against the second stable oscillator. If a one-line figure appears, it is assumed that the calibration has been made correctly up to this point. It is to be noticed that as a calibration by this method proceeds the

*cf. Formula (5).

operator has a continuous check at all times. If at any time the frequency is increased by too large an interval, it will be noticed, when checking against the higher frequency oscillator, that a mistake has been made. This, however, is merely an additional check as no mistake would be made if care is taken that the correct number of lines is obtained for each frequency setting.

When making calibrations requiring a high degree of accuracy (± 0.05 per cent), the reference oscillators are accurately checked at this point against one of the standard frequencies. If they have varied between checks, the calibration is repeated after readjusting them. If the accuracy required is not high but the relative accuracy between adjacent points is, the reference oscillators are only readjusted when a coil position or similar change is made on the oscillator being calibrated, or when a large change (± 0.02 per cent) has occurred in the reference oscillator.

The above method of calibration is used entirely except when it calls for the use of reference frequencies below 40 cycles. These cases occur only at frequencies below 300 or 400 cycles and generally are taken taken care of by one of the two following methods:

By using more complicated figures involving up to twelve lines, or by syntonizing the oscillator against another oscillator which is set progressively to frequencies which are a convenient multiple of the frequencies desired. For instance, in calibrating an oscillator with an accuracy of ± 0.5 per cent in five-cycle steps from 200 cycles to 300 cycles the reference oscillator would be set at 40 cycles and the desired points found using in turn 1-, 8-, 4-, 8-, 2-, 8-, 4-, 8- and 1-line figures. And again, in calibrating an oscillator from 25 cycles to 50 cycles in one-cycle steps, one of the reference oscillators would be set progressively at 250 cycles, 260 cycles, 270 cycles, etc., by the usual method and the oscillator being calibrated syntonized against it, using a ratio of 1:10.

Interpolation and Approximation Methods

As has already been indicated, extensive use is made of mathematical interpolation. The extension of its use is more or less an economic consideration depending upon the time and labor saved and the accuracy limitations involved. The methods used are usually approximation methods, depending for their accuracy upon the relatively small intervals at which known frequency settings on the reference oscillators may be found by means of the oscillograph. In order to use intelligently the various methods of interpolation and approximation, it is necessary to know definitely the limitations of these methods as well as the relative labor involved in their use or omission. To these ends a careful analysis of the constants of the reference oscillators has been made. The exact relation between frequency and capacity in an oscillator involves vacuum tube and circuit constants to form a theoretical relation which is too complicated for general use. However, in the type of oscillators used, it is found that the relation

$$f = \frac{K}{\sqrt{C + C_0}} \tag{1}$$

where f is frequency, C is the condenser setting capacity and C_0, is a capacity correction factor including coil and circuit capacities, holds to very high degrees of accuracy over the entire frequency range which may be covered by a single setting of the regenerative coupling. As the circuit constants are used entirely for interpolation work, the formula is used in the form:

$$\frac{f_1}{f_2} = \frac{\sqrt{C_2}}{\sqrt{C_1}} \tag{2}$$

where C_1 is the $(C + C_0)$ corresponding to the frequency f_1. The formula has been studied in this form and found to hold true to ± 0.001 per cent over frequency ranges of ± 15 per cent from f_1. The ± 15 per cent frequency range represents about the largest range which is covered by a single regenerative control position. The C_0 which must be added to the indicated setting of the oscillator may be found by substituting two known settings, and is included as part of the reference oscillator calibrations. This formula is not used, however, as in precision work its use becomes very cumbersome, due to the large amount of squares and square roots to be taken. Instead, it is expanded to the forms:

$$C_2 = C_1 - \frac{2\, C_1 (f_2 - f_1)}{f_2} + \left[\frac{f_2 - f_1}{f_2} \right]^2 C_1 \tag{3}$$

$$f_2 = f_1 - \frac{f_1 (C_2 - C_1)}{2\, C_2} - \frac{1}{8} \left[\frac{C_2 - C_1}{C_2} \right]^2 f_1 + \ldots \tag{4}$$

in which the higher order terms may be neglected for small interpolations, giving:

$$C_2 \doteq C_1 - \frac{2\, C_1 (f_2 - f_1)}{f_2} \tag{5}$$

$$f_2 \doteq f_1 - \frac{f_1 (C_2 - C_1)}{2\, C_2} \tag{6}$$

These formulas are used extensively in studies where changes of frequency with conditions are being measured. The method consists of syntonizing at any convenient ratio, one of the reference oscillators against the frequency to be studied and noting the reference oscillator setting for each condition. The relative changes are then calculated by the factor $\frac{C_2 - C_1}{2\, C_2}$ from (6). If the measurements are made over a short interval of time, the standards of frequency are not used. If the measurements are spread over an extended period of time, the reference oscillator is syntonized at the

time of each measurement against a standard of frequency at a ratio to give a setting near those obtained against the frequency under test. The differences in these settings from the first are used to correct the settings against the frequency being studied. For a great deal of the work the settings of the reference oscillator are so chosen that the air condenser difference between settings gives directly the answer in decimal multiples of per cent.

Formulas (**5**) and (**6**) are also used in measuring frequencies and in setting an oscillator at a frequency which may not be syntonized readily against the standards. To facilitate their use and to avoid their misuse, Table IIA was prepared. It gives the errors inherent to the use of the formulas as calculated from the second order term of formula (**3**). It will be seen

TABLE IIA / TABLE IIB

Interpolation errors inherent to the approximate formula: $C_2 \doteq C_1 - \frac{2\,C_1\,(f_2 - f_1)}{f_2}$		Interpolation errors inherent to linear interpolation.	
% increase of frequency calculated	% frequency error inherent in calculated setting $\frac{1}{2}\left(\frac{f_2-f_1}{f_2}\right)^2 \times 100$	% difference in known frequencies	Maximum % frequency error which may be obtained in calculated setting
0.1	+ 0.00005	0.2	− 0.0002
0.2	+ 0.0002	0.5	− 0.0009
0.5	+ 0.0012	1.	− 0.004
1	+ 0.005	2	− 0.014
2	+ 0.02	5	− 0.08
5	+ 0.12	10	− 0.3
10	+ 0.5	20	− 1.0
20	+ 2	40	− 4.0

that an error of only + 0.0002 per cent is introduced by the formulas in a 0.2 per cent interpolation. As points may be found by direct syntonization against the standards at smaller intervals than 0.2 per cent above 4000 cycles and by double syntonization below 4000 cycles, the formula may be extensively used in this connection.

Linear interpolation between two frequencies, f_1 and f_3, is also used for a large amount of work. Often it is used to replace formulas (**5**) and (**6**) in the adjustment of odd frequencies and in the determination of unknown frequencies. The inherent errors of this method have been calculated also and are given in Table IIB. Linear interpolation expressed as formulas becomes:

$$C_2 = C_3 + (C_1 - C_3)\,\frac{f_3 - f_2}{f_3 - f_1} \tag{7}$$

$$f_2 = f_3 - (f_3 - f_1)\,\frac{(C_2 - C_3)}{(C_1 - C_3)} \tag{8}$$

In the measurement of single frequencies, the frequency is known to at least its order in the usual case and to very high accuracy in a considerable proportion of cases. Methods of measuring such a frequency more accurately than it is known readily present themselves. For the few cases, where even the order of the frequency is not known, methods of preliminary estimation for determining it to a few per cent are desirable. The first step in such a procedure would be to determine if it is an audio frequency, a radio frequency or intermediate. This may be done by listening to determine if it is an audio frequency. If it is, it can be estimated from its tone more or less closely according to experience. No specific methods of similarly subdividing inaudible frequencies into ranges have been standardized but in all cases of measurement the narrowing of limits is attempted before proceeding further. After such an estimate, the frequency is placed on the oscillograph against one of the reference oscillators. Two general methods are used from this point on. In the first method the reference oscillator is set at a frequency between 20 and 200 times the frequency to be measured. The setting is also so chosen that the capacity setting is between 0.015 μf and 0.050 μf. The air condenser is then slowly decreased from a high reading to the first setting which gives a figure the number of whose lines may be determined readily. The reading is noted and the condenser setting further decreased, note being made of the easily identified patterns disclosed in the process. After decreasing the capacity 200 $\mu\mu f$. or more, the next figure to appear is held and the reading noted, together with the pattern obtained. The frequency difference corresponding to these two points is then determined from the calibration or calculated from equation (**6**) in the form

$$\Delta f = f_1 - f_2 \doteq f_1\,\frac{C_2 - C_1}{2\,C_2}$$

where f_1 is found from the calibration of the reference oscillator.

f_1 and f_2 may be expressed in terms of the unknown frequency F as follows:

$$f_1 = \left(N + \frac{X_1}{l_1}\right)F$$

$$f_2 = \left(N + \frac{X_2}{l_2}\right)F$$

whence

$$F = \frac{\Delta f}{\frac{X_1}{l_1} - \frac{X_2}{l_2}} \tag{10}$$

in which l is the number of lines in the figure and in which X is known from the order of the figures lying between the two points of observation. For instance, if the observations had been made with five- and three-line figures having a two-line and a five-line figure lying between in that order, it is obvious from Table I that $\frac{X_1}{l_1} = 0.4$ and $\frac{X_2}{l_2} = 0.666$ are the only two values which satisfy the conditions.

For the measurement of higher frequencies, there is available a similar method in which the unknown high frequency is syntonized against two lower frequencies of a reference oscillator. In this case

$$F = \left(N + \frac{X_1}{l_1}\right) f_1 = \left(N + \frac{X_2}{l_2}\right) f_2$$

from which may be obtained

$$F = \left(\frac{X_2}{l_2} - \frac{X_1}{l_1}\right) \frac{f_2 f_1}{f_1 - f_2} \qquad (11)$$

From equation (6) is found

$$\frac{f_2}{f_1 - f_2} \doteq \frac{2\,C_2}{C_2 - C_1}$$

whence

$$F \doteq \left(\frac{X_2}{l_2} - \frac{X_1}{l_1}\right) \cdot \frac{2\,C_2}{C_2 - C_1} \cdot f_2 \qquad (12)$$

In using the methods just described, an accuracy of 2 per cent or 3 per cent is desired. To meet this accuracy, the ratio of $\frac{C_2 - C_1}{2\,C_2}$ or of $\frac{f_1 - f_2}{f_2}$ must be reasonably small (0.02 or less) in order that the approximation of equation (6) will be satisfactory. It is necessary that $(C_2 - C_1)$ may be read to three significant figures and it is necessary to include in C_2, C_0 to the third significant figure of C_2.

Special Circuits

Mention has been made of the fact that various means are available for making the "front" and "back" of the patterns readily distinguishable. There have been devised for this purpose many circuits, some of which have been used in connection with the equipment described in this paper. These auxiliary circuits may be divided roughly into two classes; the first, those in which the beam is caused, by the base frequency and its auxiliary circuit, to traverse the screen much more rapidly in one direction than in the other so that the "back" pattern is spread more than the "front" and even may be so faint as to be invisible, and the second, those in which the "back" of the pattern actually is displaced above or to the side of the "front" pattern.

Those belonging to the first class have been used more often. Perhaps the simplest to use is that of distortion in the auxiliary vacuum tube circuits of the measurement equipment. For instance, in the case of the standard frequencies, by overloading the vacuum tubes of the amplifiers and by using interstage transformers which for any other work would be considered unsatisfactory, sufficient distortion is produced to make the "front" of the picture stand out much more clearly than the "back" of the picture. Consequently, in the larger volume of routine work, this method is used entirely. In precision work, it has a slight advantage in that the "back" pattern is of a larger amplitude than the other and magnifies any lack of syntonization.

One of the simplest methods of separating the "front" from the "back" of the picture is by means of the circuit [4, 5] shown in Fig. 14. The reference oscillator output is stepped up to a high voltage by means of transformer, T_1, and placed across a resistance, R, and capacity, C, which are in series and have their

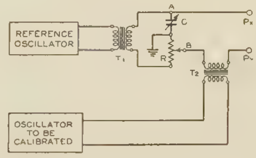

Fig. 14

common point grounded. The condenser is made variable to facilitate the adjustment of its impedance in accordance with the frequency of the input. In the more useful case the resistance would be in the form of a potentiometer in order that a variable voltage might be taken from it. If, with a small input to T_1, the voltages at A and B are placed on the cathode ray oscillograph, there will result an ellipse, for the voltages across the resistance and across the condenser are at right angles to each other. If the secondary of transformer T_2 is placed between B and the oscillograph and the primary is connected to the unknown frequency, there will result on the oscillograph after syntonization a figure such as is illustrated by Fig. 8. If the input to transformer T_1 is increased, the ellipse may be so enlarged that it will lie outside the oscillograph screen. However, by adding a d-c. component by means of the biasing potentiometers of the oscillograph, one portion may be placed at the center of the screen and figures such as those illustrated by Figs. 9 to 13 will result. In this circuit, the separation of the "front" and "back" of the pictures is controlled by the setting of the potentiometer at A and the spread of the pictures by the input to T_1. The condenser is varied with frequency to place an optimum impedance load on the transformer.

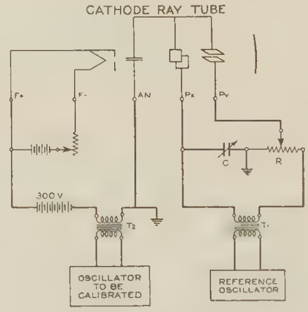

Fig. 15

Another circuit which often is useful is that shown by Fig. 15[5]. As in the previous circuit, the reference

frequency is applied in quadrature to the two plates of the oscillograph. In this instance the value of the resistance and of the condenser impedance are made equal so that, with zero biasing potentials on the oscillograph, a circle appears on the face of the screen. The unknown frequency is then placed in series with the cathode potential by means of transformer T_1. The effect of a change in the cathode potential is to change the sensitivity of the oscillograph, thus enlarging the radius of the circular trace. When the cathode potential is varied by an alternating potential which varies the radius syntonously with the base frequency, a pattern such as shown in Fig. 9 results. This method of separating the "back" and "front" of the picture has found considerable use in radio frequency measurements. However, the circumference of the trace is limited by the circumference of the oscillograph screen which limits the usefulness of this circuit for one of two reasons. The ratio which may be used with such a circuit is limited to something in the order of 1 to 50 and at low frequencies the spread of the unknown frequencies can not be made large enough to obtain high precision.

Several other circuits of limited value have been tried. One which is interesting because it involves the much used charge or discharge curve of a condenser is shown in Fig. 16. It is used for the measurement of the frequency of vibrating contacts. Specifically, it is more often used for the measurement of tuning forks which have driving contacts. The figure merely illustrates one of the numerous ways in which the circuit may be set up. In this instance, when the contact is made, both terminals of the condenser are grounded and the condenser is in a discharged condition. When the contact opens, the condenser is

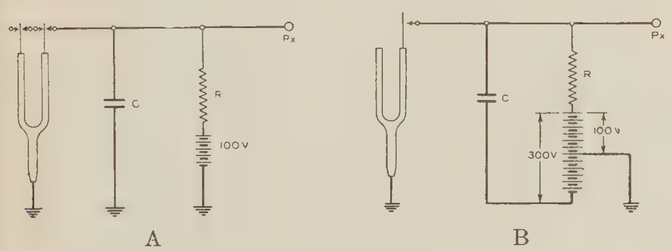

Fig. 16

charged at a rate controlled by its value and by the value of the resistance in series with it and some convenient potential. The result is a saw-tooth shaped voltage wave form across the condenser, which is an optimum type of wave shape for frequency measurement. The figure produced by such a system is very similar to that illustrated by Fig. 7, although the "back" lines shown in Fig. 7 are invisible, as the potential of the condenser is reduced to zero instantaneously by the closing of the contact. Fig. 16B illustrates a modification which gives an essentially straight line sweep of the beam.

A large number of precision measurements have been made on stroboscopic forks. In this instance, a circuit was used which, while not a circuit relating to the oscillograph, is given to illustrate the wide diversity of measurements and circuits which are used in connection with the frequency measurement equipment. This circuit is constructed by merely placing in the output of one of the reference oscillators a high-ratio transformer, across the secondary of which is connected a neon lamp. The oscillator is then adjusted to twice the frequency of the fork by viewing the neon lamp through the fork and varying the oscillator condensers until the glow is either steady or not seen at all. This measurement

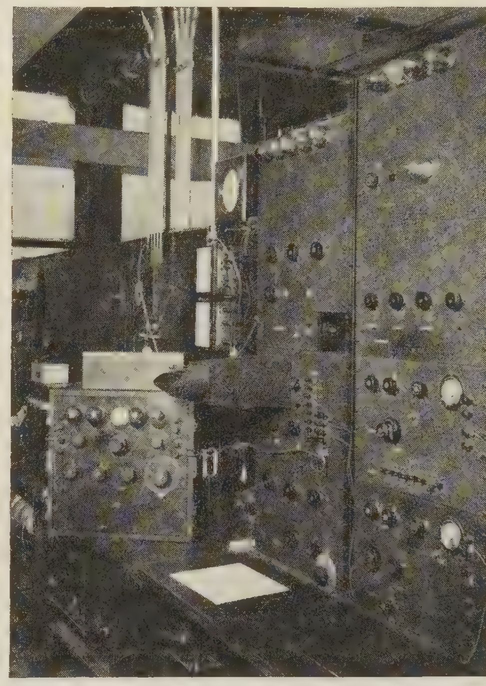

Fig. 17—A Cathode Ray Oscillograph Equipment

Containing an oscillograph, two oscillators, a 300-volt rectifier, and a standard-frequency control panel.

gives the frequency of the fork within a fraction of a per cent. If a higher precision is needed, the oscillator is set at approximately 10 to 20 times the frequency of the stroboscopic fork. Its output is increased to the point where the neon tube just discharges. It is now found that the oscillator can be syntonized to the fork to a very much higher precision.

Conclusion

The methods and apparatus described were first developed for laboratory precision measurements. They have been in use for several years during which time it has been amply demonstrated that they are suitable not only for the technical measurements of a development and research nature but are equally adaptable for routine commercial work. The advantages which particularly commend themselves are the rapidity with which such work may be done and the ease with which the average man can learn the work.

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The Remote Control of Multiple Street Lighting

BY W. T. DEMPSEY[1]

Member, A. I. E. E.

Synopsis.—*This paper describes control systems for multiple street-lighting systems and deals particularly with the systems employed in New York City. The paper is introduced by a brief history of the development of street lighting since 1879 when the series system, the first street-lighting method, was established.*

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As established in 1879 by the pioneer Charles F. Brush, the generally accepted method of lighting streets and public highways, in so far as the lamp-to-lamp connection and the electrical distributing system are concerned, was by means of the series system which, to this day, is familiar and which down through the years has remained, to a very large extent, as the standard method of electrical connection and distribution for supplying service to street lamps.

With the exception of the Borough of Manhattan, in the City of New York, where certain of the streets since 1892 have been lighted in part from the multiple underground commercial network, the series method of service supply has been universally used throughout the country and only within the past several years has any serious attention been directed toward the possibility of lighting streets in congested areas by means of service supplied from the multiple low-tension commercial source. Many installations are in operation with a combination of series and multiple connections, where the lamps themselves are supplied from a multiple service from a 2300-volt primary feeder and a transformer of 110 to 220 volts secondary, the secondary circuit being opened and closed by means of a relay actuated by a nearby series circuit and such relay, in turn, opening and closing a multiple switch on the transformer secondary service supply or by time clock. Also, there are many installations operated from series circuits where a transformer is placed in the circuit for each individual lamp, the primary being energized from the series circuit while the secondary of the transformer is connected in multiple across the lamp terminals, increasing the lamp amperage with consequent improved efficiency. This same combination of circuit is used where a number of series lamps would be connected in a somewhat similar transformer secondary. No doubt the most noteworthy advance in series street lighting was the development some years ago of the constant current transformer, which eliminated the necessity of separate series generator source of supply, all of which indicates, when compared to the original 9.6-ampere series circuit as established by Mr. Brush and which is even standard to this day in many cities, that there has developed over the period of years a flexibility of service supply and control of series street lighting circuits which is advantageous and commendable and which can be applied in many localities where local conditions, for both overhead and underground distribution, are such as to warrant its use.

Previous to November 1892 the limited electrical street lighting of those days in the City of New York was served by means of series overhead lines, but in this year, with the development of the low-tension constant-potential arc lamp, The New York Edison Company entered the field of street lighting.

Today all the street lighting in the Borough of Manhattan is served from a multiple source; that of The United Electric Light and Power Company from a 110- to 220-volt underground main and that of The New York Edison Company from a 120- to 240-volt underground main, the mains in each instance being the same network as used for service supplied to abutting buildings. Also in the Borough of the Bronx, served by The New York Edison Company, the extension of the multiple street lighting system is progressing from year to year and as in the Borough of Manhattan is operated by the a-c., 60-cycle underground commercial distributing system of 110/220 volts. As of August 1st, 1926, within these two boroughs 70 per cent of the light sources are served from the multiple system, the lamps ranging in size from 25 to 750 watts.

As the growth of the system continued, the lamps were turned on and off by means of a switch in the individual posts, or in many cases groups of posts were turned on and off by a single switch. Also in the lighting of the several parks throughout the city,

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1. Superintendent Service Maintenance Dept., New York Edison Co., 38 West 17th St., New York City.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

where a number of lamps were controlled from a single source, each individual circuit was turned on and off by means of time clocks placed in the base of the lamp posts. In 1918, however, the control system as now used was perfected after considerable experimental and development work. Bearing in mind that street lighting is a most important branch of the service rendered by a public utility and particularly so in the congested areas of the larger cities of the country, any system must be so designed as to render the highest degree of reliability. In adopting this method of street-lighting control, therefore, the factors governing the installation are:

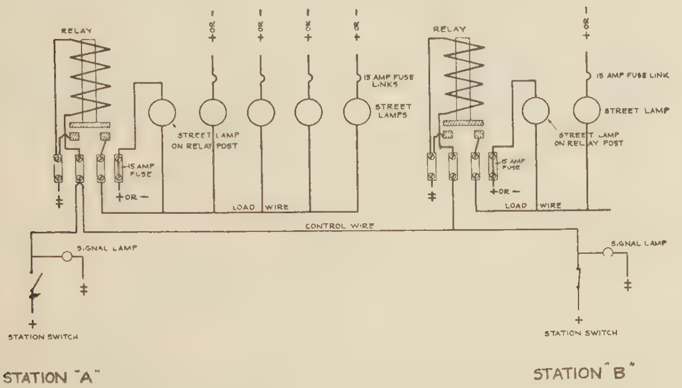

FIG. 1—WIRING DIAGRAM OF REMOTE CONTROL FOR MULTIPLE STREET LIGHTING
Showing Typical Street Intersections

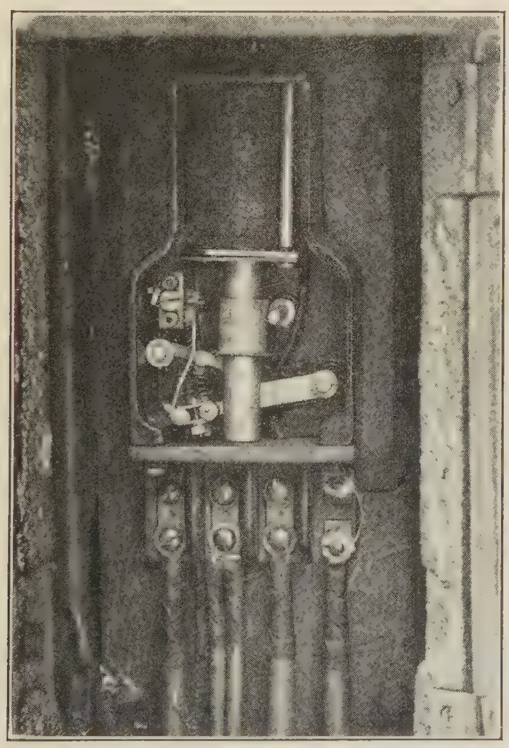

FIG. 2—STREET LAMP POST RELAY INSTALLATION

First. The controlling circuit must be so designed that outage of a number of street lamps, due to a fault in the control wire or defective relay, is practically eliminated. This is the most important requisite.

Second. The system should be flexible as to control, allowing various means to turn the lamps on and off as required, from several sources of supply.

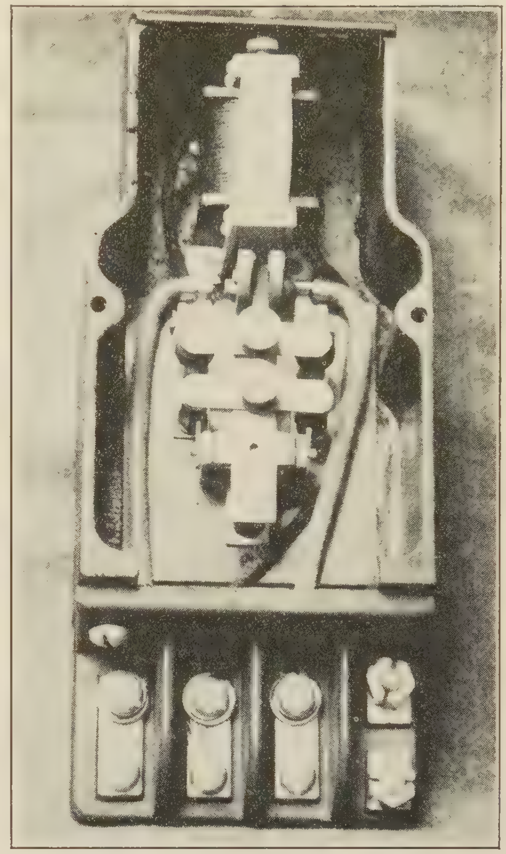

FIG. 3—RELAY ASSEMBLAGE

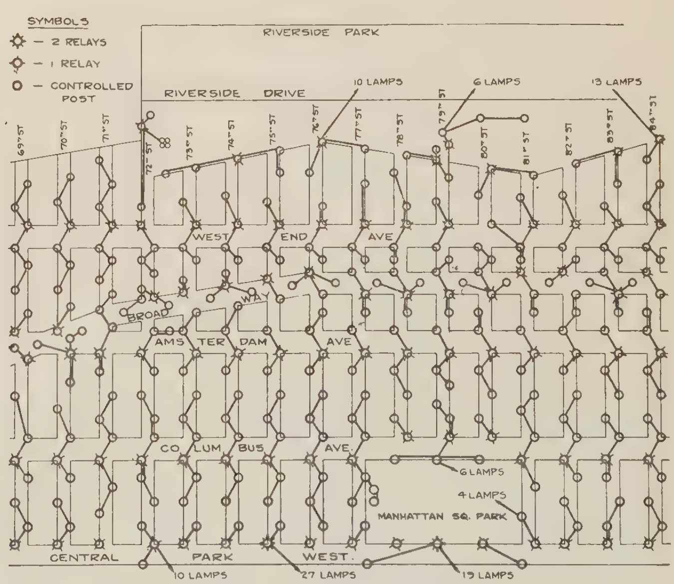

FIG. 4—TYPICAL MULTIPLE STREET LIGHTING REMOTE CONTROL (AREA 64TH TO 84TH ST., WEST SIDE, NEW YORK CITY)

Third. The relays should be so designed as to open and close the circuit with the least possible complication of moving parts; it should be positive in its action and close the lighting circuit by means of gravity. A

relay so designed is not dependent on potential for lighting the street lamps but rather to put them out, and when so designed the likelihood of extensive outage is extremely remote, as the lamps will light in case of accidental open circuit of the control wire. This will be seen more readily by referring to wiring diagram, Fig. 1.

The system of control as installed by both The New York Edison Company and The United Electric Light and Power Company follows the diagram shown in Fig. 1. The control wire is lead covered No. 10 or No. 12 B & S rubber insulated and pulled into the distributor ducts occupied by the commercial main cables. These ducts will vary in size from 3 in. to 3½ in. and before installing the street lighting load or control circuit will contain three cables varying in size from 200,000 to 750,000 cir. mils. The ducts are rodded by means of a ⅛ by ⅝ steel "fish." As shown in Fig. 1, the control switch is closed in Station "B," the relay solenoids being energized, the armature being held in suspension, and the street lamps being out. The signal lamp is lighted in Stations "A" and "B," indicating as an operating detail that the control wire is continuous. The relay connections shown in this diagram can be seen in a photographic reproduction of an actual relay installation, shown in Fig. 2, with a closer view of the relay connections and one type of internal mechanical relay assemblage shown in Fig. 3. The over-all dimensions of these relays are 2¼ in. by 4 in. by 9 in., the coil consuming from seven to ten watts, while the main contact is specified to carry, make and break a load of 25 amperes.

For purposes of more accurately illustrating an area within the City of New York, controlled in the manner shown in Fig. 1, attention is called to Fig. 4, covering that section of the City of New York between 64th and 84th Streets and from Central Park West to Riverside Drive and the Hudson River, an area approximately 1 mi. long and ¾ of a mi. wide. This plan shows the relays as installed at each street intersection and the lamps controlled by these relays, while Fig. 5 is a wiring diagram of the control circuits within this same area.

In Fig. 1 it will be noted that the control wire is looped into one relay while teed into the other. This system of connection is used throughout, the loop connection being made on even numbered streets, while the tee connection is made at the odd numbered streets. The object of the loop connection is to provide facilities to enable the breaking up of the control wire in case of necessity, such as testing purposes, into any number of sections that may be required. It also provides a means whereby a particular circuit can be controlled from any street lamp post so connected. The signal lamp shown connected in the control circuits in both Fig. 1 and Fig. 5, is alight when the control wire is alive and indicates continuity of the control wire throughout its entire length.

Fig. 6 is a section of remote control route map, illustrating in diagram form routes of several control wires

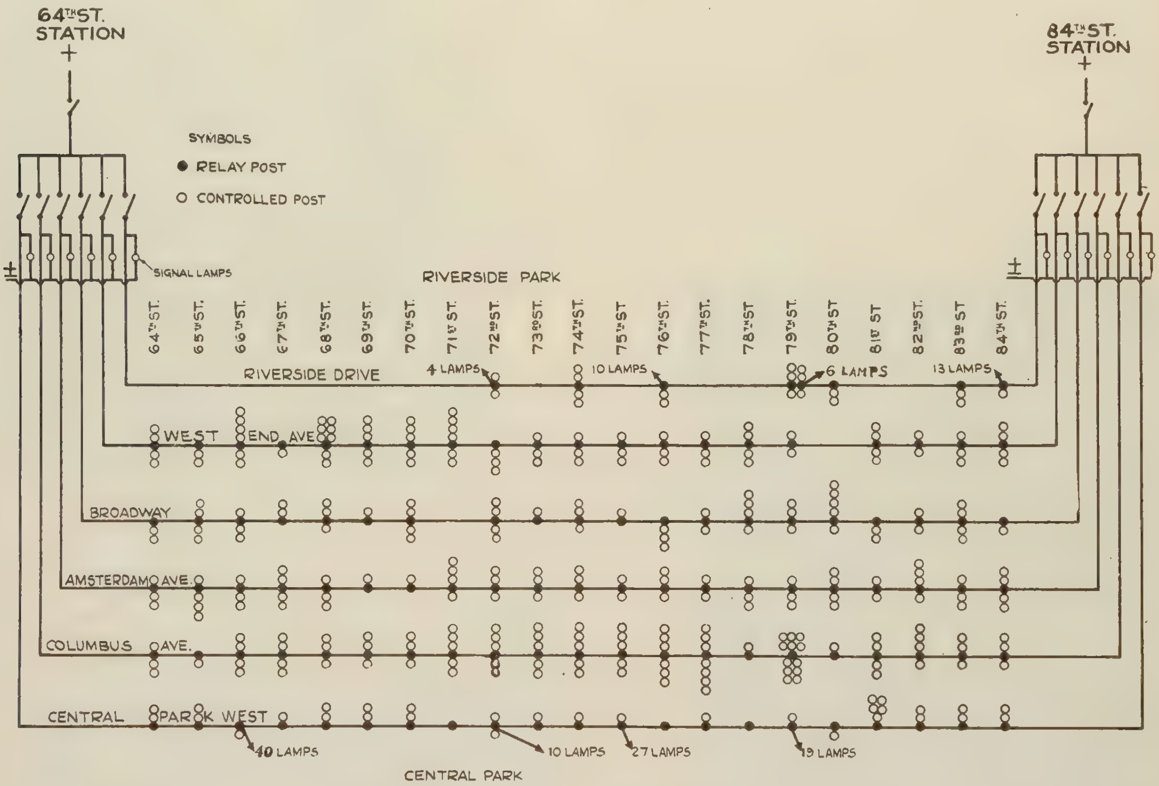

Fig. 5—Wiring Diagram for Lamps Controlled by Each Relay (Area 64th to 84th St., West Side, New York City)

from station to station. It shows that control wire will leave one station and terminate in another. Also certain control wires will route out of one station and return to the other station, while in certain other sections the control wire will be teed, the object of such a layout being that there is a check at all times on the continuity of the control wire circuits. Particular substations are selected as operating stations for the turning on and off of the street-lighting system. Those substations shown in the solid squares, such as 84th Street and East 123rd Street, are operating stations, while the blank square as shown by the 107th Street Station is an emergency control point. To illustrate

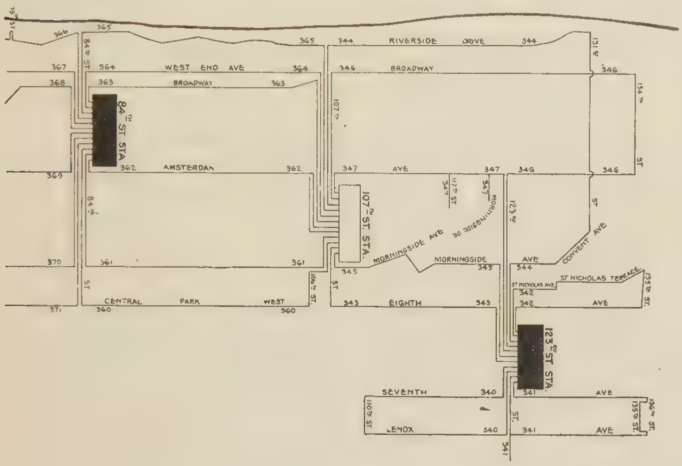

Fig. 6—Section of Remote Control Layout (The New York Edison Company)

this point further, 84th Street Station is within the area shown in Fig. 6. This station controls all the lighting on the west side of New York from 64th Street to 107th Street, the control board operating 12 control circuits all connected in the manner shown in Fig. 1, so that with the opening or closing of these 12 small switches on the street lighting control board in this station, 1390 lamps are turned on or off within an area approximately $2\frac{1}{8}$ mi. long and $\frac{3}{4}$ of a mi. wide. A further advantage in having either end of a control wire in hand is that it enables operation from both ends, in case of necessity, for subway construction purposes or any changes that may be necessary in the main distributing cables occupying the same duct with the control wire. Also this either-end connection would permit the installation of a time clock for the control of these circuits.

The system of control as used by the United Electric Light and Power Company in the Borough of Manhattan, City of New York, is somewhat different in that there is a relay in each post controlling either the individual lamp or a number of lamps as desired, the control wire being opened and closed by means of a time clock placed in a street lamp post approximately within the center of the control area, with an extension of the control wire into the nearest substation where an indicating lamp is connected to show that the time clock and control circuit are functioning properly.

Again referring to Fig. 1, the connections are identical with the actual photographic reproductions of the terminal block connections in Figs. 2 and 3, where the left hand terminal is the system neutral, the one to the right being the control circuit, the next being the load wire connection, while the extreme right hand terminal is a fuse connection on the outside polarity for the particular lamp on the post in which the relay is installed. It will be noted that the make and break of the main circuit is through the system neutral or grounded connection, the outside positive or negative polarity being connected in the individual lamp post through a 15-ampere fuse. For load balancing purposes on the system, the outside polarity of lamps connected to one relay at a certain street intersection will be connected to the negative side of the system while on the next street the lamps will be connected to the positive side of the system. Making and breaking the system neutral on the load wire circuit was done pur-

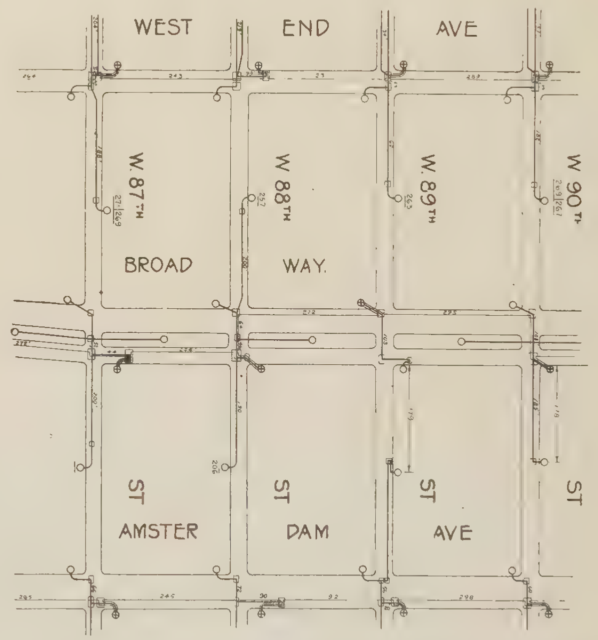

Fig. 7—Actual Layout With Load Wire and Control Wire Running Through Manholes and Handholes

posely so that at night in case of a relay fault it is only necessary to ground the load wire, at any convenient point, in any one of the several street lamp posts served and the lamps can be lighted in this manner while changes or repairs to the relay can be made conveniently the following day. In leaving the lower terminal block exposed as shown in Figs. 2 and 3 this feature was in mind so that the connection could be quickly and conveniently accessible for change and repair purposes.

Operating characteristics of the relay shown in Figs. 2 and 3 are as follows:

D-c. relay, with the solenoid cold:

Pick-up voltage.......83.5
Drop-out voltage.....18.9
Pick-up wattage...... 3.34

After several hours of operation and a temperature rise in the solenoid:

Pick-up voltage.......93.3
Drop-out voltage.....23.9
Pick-up wattage...... 3.63

Fig. 7 shows an actual layout with load wire and control wire running through manholes and handholes, in the subway distributing system, from the substation in 84th Street between Amsterdam Avenue and Broadway through the territory between West 87th Street and 90th Street. This plan also shows the location of each street lamp post with the number of the house in front of which it is located.

TABLE A
POSTS IN THE CONTROLLED AREA
64TH STREET TO 84TH STREET WEST SIDE
(The New York Edison Co.)

Circuits	Relay posts	Controlled posts	Total posts
Riverside Drive No. 366	8	52	60
West End Avenue No. 367	20	81	101
Broadway No. 368	20	55	75
Amsterdam Avenue No. 369	21	76	97
Columbus Avenue No. 370	21	95	116
Central Park West No. 371	24	132	156
Totals	114	491	605

Table "A" shows the number of relays and posts controlled within this area on each control wire, the relay posts being 114 in number and the controlled posts 491, or a total number of 605 posts controlled within this area.

Table "B" indicates the various sizes of lamps controlled within this area and it will be noted that the average number of lamps per relay is 5.3.

Table "C" indicates the total load control in this area and the control wire load, the total load controlled being 1234.3 amperes or 148.1 kw. while the control wire energy required to handle this load is 7.3 amperes or 0.87 kw.

The total annual kw-hr. consumption of the controlling load and street-lighting load is 592,400 kw-hr. street-lighting load controlled by 416 9.7 kw-hr. control wire energy per year within the territory from 64th to 84th Streets, Central Park West to the Hudson River as previously shown.

The station control board capacity necessary for the operation of this system of street-lighting control is a panel 2 ft. wide and 6 ft. high, on which are mounted one main service switch, shown in Fig. 5, which in turn is connected to a number of small 10-ampere, single-pole, single-throw switches also shown in Fig. 5. The station signal lamps are 10-watt bull's-eye design.

TABLE B
SIZES OF LAMPS IN REMOTE-CONTROL AREA 64TH STREET TO 84TH STREET WEST SIDE
(The New York Edison Co.)

Circuits	Relays	Lamps							
		25-W.	100-W.	150-W.	200-W.	300-W.	400-W.	500-W.	750-W.
Central Park West	24	9	59	39	15	9	..	25	..
Columbus Avenue	21	10	8	..	41	16	41	..	..
Amsterdam Avenue	21	9	..	..	35	5	48	..	..
Broadway	20	4	..	..	12	22	34	..	3
West End Avenue	20	8	..	..	50	25	16	2	..
Riverside Drive	8	4	33	..	6	5	15	..	..
Totals	114	44	100	39	159	82	154	27	3

Total number of relays—114
Total number of lamps—608
Average lamps per relay—5.3

TABLE C
REMOTE-CONTROL MULTIPLE STREET LIGHTING AREA
64TH STREET TO 84TH STREET WEST SIDE
(The New York Edison Co.)

Circuits	Total lamps	Total amperes	Kw. load	Control wire	
				amperes	Kw.
Central Park West	156	247.2	29.6	2.00	0.24
Columbus Avenue	116	253.7	30.4	1.35	0.162
Amsterdam Avenue	97	232.7	27.9	0.76	0.091
Broadway	75	189.1	22.7	1.12	0.134
West End Avenue	101	209.1	25.1	1.35	0.162
Riverside Drive	63	102.5	12.3	0.70	0.084
Totals	608	1234.3	148.0	7.28	0.873

Total load controlled—1234.3 amperes
Total load controlled— 148.0 kw.
Control-wire energy — 7.3 amperes
Control-wire energy — 0.87 kw.

As previously stated, great progress has been made over a period of years in the application of various forms of series lighting circuits and combinations of series and multiple circuits. With the development of the straight multiple control system described above, there has been brought to the art of street lighting an added system of reliability of supply, flexibility of control and distribution.

In the preparation of this paper the author appreciates the cooperation of Mr. A. H. Kehoe, Electrical Engineer, The United Electric Light and Power Company, New York City.

Operating Requirements of the Automatic Network Relay

BY W. R. BULLARD[1]

Member, A. I. E. E.

Synopsis.—*This paper describes, in an elementary manner, the various relations between distribution system characteristics and the design characteristics of the relays which are used to provide automatic control for the so-called automatic, low-voltage, a-c. network distribution system.*

In the first part of the paper the general principles of operation of the relays and the limits of magnitude of the various actuating forces are discussed; in the latter part, the relations between distribution system characteristics and the phase angles involved in the operation of the relays are described.

It is shown that relays having simple watthour-meter characteristics are not fully applicable to all network systems of the automatic type, but are generally applicable to those having certain limited characteristics. Relay characteristics which would have practically universal application are described and a brief discussion as to the future trend of development is included.

DURING the past two or three years several new types of distribution systems classed under the general designation "a-c., low-voltage networks" have been placed in service. Closely connected with the development of the most widely used one of these new types of systems has been the development of a new type of protective apparatus. An individual unit of this apparatus consists essentially of an electrically operated circuit breaker, controlled by one or more relays of a special type, called, for convenience, "network relays." Descriptions of this apparatus and of its application to a-c., low-voltage network distribution are available in the technical literature[2].

The special type of protective apparatus to which reference is made here is automatic in both the opening and the closing operations of the circuit breaker, and the network relay is called upon to supply the control impulses for both operations. The currents and voltages which are used to actuate the relay are related to each other in a somewhat complicated manner and the interrelations of these quantities are dependent upon various physical characteristics of individual a-c. network distribution systems. The design of the relay must therefore be fitted to the physical characteristics of the distribution system in which it is to operate, and, conversely, the design of the distribution system must take into account the limitations of design of the relay. The distribution engineer must be cognizant of the principles involved in the operation of the apparatus and must be thoroughly prepared to cooperate with the manufacturer in fitting together the characteristics of the distribution system and of the network relay, at least until such time as the design of one or both may have become reasonably standardized.

The purpose of this paper is to make available in elementary and condensed form, from the standpoint of the distribution engineer, information concerning the various relations between system characteristics and network relay design, which theoretical considerations and recent operating experience have shown to be important in the successful operation of the system as a whole.

Although the operating requirements of the relay are rather complex, its actual construction and operating adjustments may be quite simple. Details of the construction and operating characteristics of a particular design of network relay have been described in an article by J. S. Parsons[3]. Additional data from the standpoint of the designing engineer will be presented in two companion papers to this one[4]. In this paper, therefore, reference to design details will be avoided so far as possible.

General Principles of Network Relay Operation

Referring to Fig. 1, the two principal functions of a network relay are to supply the opening impulse of the circuit breaker when conditions are such as to require opening, and to supply the closing impulse when conditions are correct for closing.

The condition which ordinarily requires opening of the breaker is that the flow of energy shall be in the direction from the low-voltage network toward the transformer. Such a condition may be caused by the opening of a feeder circuit breaker at the source of supply or by a short circuit in a transformer or high-voltage circuit. In the first case the reverse flow of energy is caused by the magnetizing losses of the distribution transformers being supplied from the network

1. Assistant Engineer, Electric Bond and Share Co., 71 Broadway, New York City.

2. "The Automatic Alternating-Current Network Protector," G. G. Grissinger, *Electric Journal*, August, 1923.

Underground A-C. Network Distribution for Central Station Systems, A. H. Kehoe, A. I. E. E. JOURNAL, June, 1924.

"Alternating-Current Secondary Networks," D. K. Blake, *General Electric Review*, June, 1923.

Study of Underground Distribution Systems for the City of New Orleans, W. R. Bullard, A. I. E. E. JOURNAL, Nov., 1924.

Several Articles on A-C. Network Distribution Systems and Apparatus in the *Electric Journal* for July, 1925.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

3. "The Automatic Network Relay," J. S. Parsons, *Electric Journal*, July, 1925.

4. A-C. Network Relay Characteristics, D. K. Blake.

Design of Automatic Network Relays, J. S. Parsons.

instead of directly from the source of supply as under normal conditions.

The condition which ordinarily requires the closing of the breaker is that the relation between the voltage of the network and that of the transformer banks which are to be connected shall be such as to cause a flow of energy from the transformer toward the network after the closing operation is completed. This flow of energy

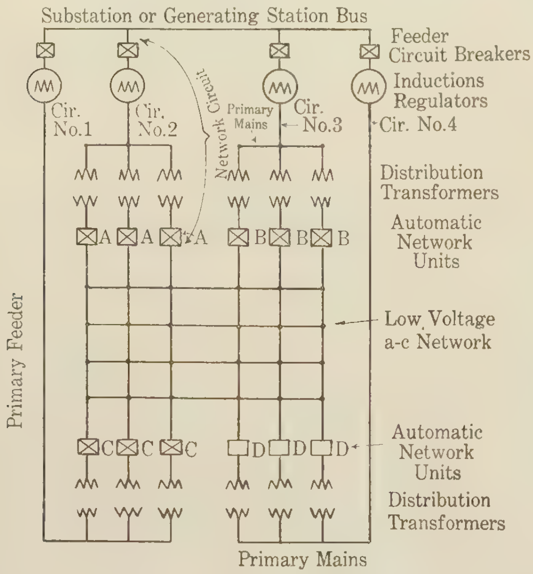

FIG. 1—DIAGRAM SHOWING THE PRINCIPAL ELEMENTS OF AN AUTOMATIC, LOW-VOLTAGE, A-C., NETWORK DISTRIBUTION SYSTEM

must not be accompanied, of course, by undesirable cross currents such as would be the case if the phases of the circuit to be connected were twisted (by incorrect connections of the supply conductors) with respect to those of the network.

In order to meet the above conditions, the actuating forces of the relay are ordinarily obtained from three local circuits (see Fig. 2); namely, the potential circuit which is connected in shunt to the line conductors on the network side of the circuit breaker and therefore represents network voltage; the current circuit, which obtains current from the line conductors when the circuit breaker is closed and therefore represents line current; and the phasing circuit which is connected from one to the other contact of a single pole of the circuit breaker and therefore represents the voltage difference between network and transformer. The opening operation is controlled by the interaction of the potential and current circuits, while the closing operation is dependent upon the interaction of the potential and phasing circuits. In some designs of network relay, the phasing and current circuits are interconnected so as to utilize a single winding in the relay for the two circuits.

Under one condition,—namely, when the network is dead and is to be made alive by the energizing of one of the primary circuits,—one of the actuating forces, (voltage for the potential circuit) is missing and an independent mechanical force must be supplied to insure the relay contacts being in a position to cause the closing of the circuit breaker. This is usually accomplished by the use of a spring which holds the contacts in the closing position when the electrical circuits of the relay are entirely dead. Since, under normal conditions, a delicate balance must be maintained between opening and closing torques, the force of the spring is neutralized by the action of a local shading circuit when the network is made alive.

Both magnitude and phase relations of the actuating currents and voltages are involved in the operation of the relay. For simplicity, the magnitudes of the forces involved will be discussed separately from the subject of phase relations.

MAGNITUDE OF ACTUATING FORCES

In the opening operation there are two extreme limits of current magnitude which may exist in the main line conductors. The lower limit, fixed by the magnetizing current of the transformers together with the charging current of the high-voltage conductors, is involved when it is desired to disconnect a circuit by opening the primary switch at the source of supply. With primary voltages on the order of 2300 or 4000 volts, the reactive component of the transformer magnetizing current, under usual system characteristics,

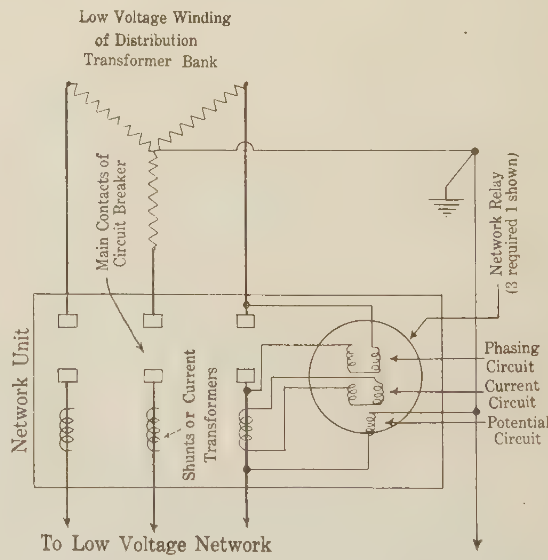

FIG. 2—SIMPLIFIED WIRING DIAGRAM OF NETWORK RELAY CONNECTIONS FOR THREE-PHASE, FOUR-WIRE SYSTEM. (THREE RELAYS REQUIRED—ONLY ONE SHOWN)

will predominate over that of the line charging current. With primary voltages on the order of 13,200 and above, the reactive component of line charging current will sometimes predominate over that of transformer magnetizing current. Obviously, therefore, there will sometimes exist conditions in which the reactive components of these two currents will neutralize each other, leaving only the energy components of both currents. To make the operation absolutely certain,

therefore, the torque produced by the energy components of transformer magnetizing current and line charging current in combination with network potential should be sufficient to actuate the relay. The value of the sum of the two former components is usually less than one per cent of normal full load current.

On the other hand, the short-circuit current produced by a failure of transformer or primary line insulation must produce the same action in the relay without damaging it mechanically or electrically. Primary line short-circuit currents are limited by the short-circuit impedance of the distribution transformers, but transformer short circuits may involve very high values of current, the worst case being a dead short circuit at the low-voltage terminals of the transformer or at the conductors leading from the transformer to the network protective unit. In this case a large proportion of the full amount of current which the network is capable of supplying from the circuits which are not in trouble may flow through the line conductors of a network unit. The value of this current may be 20 or 30 times normal full-load current, or even more in certain cases. The network relay, therefore, together with its line current transforming device (line shunt or current transformer), is called upon to function properly throughout an enormous range of current in the opening operation. The duty on the relay itself is ordinarily reduced by magnetic saturating characteristics of the line shunt or current transformer.

In the closing operation the relay obtains its torque from the voltage difference between the network and the transformer, in combination with network potential. This voltage difference may be produced by different positions of the primary feeder regulators, if such exist; or may be due to the voltage drop from the source of supply to the network due to the load on the latter; or may be due to a combination of both causes. In the second case the voltage difference is limited by the load and the system impedance, and the value at which the relay must function is therefore dependent upon the system characteristics and upon the percentage of load at which it is desired to connect a feeder to the system. In case feeder regulators are used, any value of voltage difference may be obtained up to the limit imposed by the range of regulation. In any case, however, the voltage difference necessary to operate the relays should be small in order to avoid cross currents and fluctuations of the network voltage immediately after the closing operation. A fair minimum voltage difference necessary to operate the relay, for average systems, is probably one per cent of normal network voltage in phase with the latter.

When the primary circuit is dead and the network alive, practically full line voltage in the opening direction is impressed across the phasing circuit of the relay; or if the primary circuit should be made alive, with its phases twisted with respect to those of the network, more than full line voltage may be impressed across the relay phasing circuit. Thus, in connection with the control of the closing operation, the relay and its phasing circuit must be designed to operate properly under an enormous range of voltage variation. The duty on the relay is ordinarily reduced by the insertion of a small tungsten lamp in the phasing circuit. This lamp limits the range of current in the phasing circuit by virtue of the rapidly increasing resistance of the filament with increasing temperature.

Under normal conditions it is not permissible, either in the closing or the opening operation, for the relay to operate at zero values of voltage in the phasing circuit or current in the current circuit, since this is on the borderline of incorrect operation and provides no factor of safety against "pumping," *i. e.*, opening and closing periodically for an indefinite length of time. There must therefore be a certain amount of torque difference, produced either electrically or mechanically, between the opening and the closing positions of the relay disk. With a double contact relay, one contact for opening and one for closing, this effect can be obtained by the difference in spring tension between the two positions where contact is made. With a single contact relay, an auxiliary circuit is ordinarily used to provide a slight change in torque when the contact is made or broken. This torque difference must be definite and the adjustments should be such that some torque in the opening direction produced by the current circuit is necessary to cause opening action and some torque in the closing direction, produced by the phasing circuit, is necessary to cause closing action.

As mentioned above, since the relay contacts must be in the closing position when the network is dead, a spring is ordinarily used to provide the necessary torque. When the network is alive the force of this spring is neutralized by a local shading circuit arrangement which acts in magnetic combination with the potential circuit. The adjustments are of course ordinarily made to just balance the force of the spring at normal voltage on the network. Since network voltage is not necessarily exactly normal at all times, it is obviously necessary that the value of the torque produced by the shading circuit be such that the operating characteristics of the relay are not materially changed by ordinary variations of network voltage; *i. e.*, it is necessary to insure that enough closing torque at low network voltage will not be produced to cause incorrect closing and that enough opening torque will not be produced by high network voltage to cause incorrect opening. Nevertheless the strength of the spring must be such as to cause positive closing with a dead network. This is a matter of properly proportioning the forces in the design of the relay. In order to provide the proper factor of safety under normal operation, however, a range of probably 20 per cent voltage variation above or below normal (considering average systems) should not cause the relay to operate with the phasing and current circuits de-energized.

Phase Relations

Relations Between Phasing Voltage and Line Current. In the greater part of the following discussion only one phase of a polyphase system will be considered, since with the use of single-phase relays, the action with respect to each of the phases of the system is, in general, the same as the action would be in an isolated single-phase system.

Consider the conditions shown in Fig. 1 which is a diagrammatical representation of a network system having four primary circuits. Circuits Nos. 1, 2, and 3 are in service and carrying load, both high-voltage circuit breakers and low-voltage network circuit breakers being closed as indicated by the *X*'s in the circuit breaker symbols. Circuit No. 4 has been made alive at the supply station by the closing of the primary circuit breaker, but the network circuit breakers, *D D*, have not yet closed. Assume for the present that the impedance of high-voltage and low-voltage cables is negligible in comparison with the impedance of distribution transformers. This assumption is not strictly justified except in cases of high reactance transformers

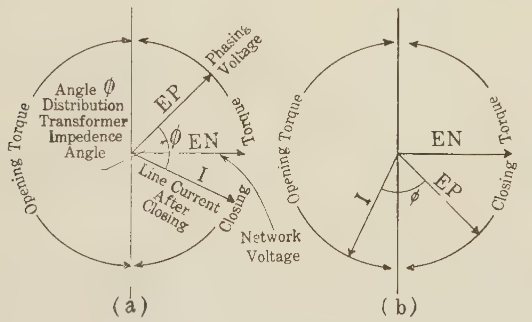

FIG. 3—POLAR DIAGRAM OF PHASE RELATIONS IN A NETWORK RELAY HAVING SIMPLE WATTHOUR METER CHARACTERISTICS

of reasonably close spacing, connected by low-voltage mains of large cross section. The error introduced by this assumption, however, can be compensated for by adjustments of the relay, and this will be discussed later.

Under the above conditions a voltage difference will exist between the two sides of the network units, *D D*. This voltage, which, for convenience will be called the phasing voltage, controls the closing operation of the network units and may be produced either by the voltage drop through the transformers of circuits Nos. 1, 2, and 3, or by a difference of settings of regulators on circuits Nos. 1, 2, and 3 as compared with circuit No. 4, or by both voltage drop and regulator settings. Now if this phasing voltage is of such magnitude and phase relation as to cause sufficient closing torque in the network relays, network units *D D* will close. After the closing operation, a current will be set up in circuit No. 4 due to the phasing voltage which existed before the closing. This current will take the form of a circulating current between circuit No. 4 on the one hand and circuits Nos. 1, 2, and 3 in parallel on the other hand, a complete circuit being formed by this combination from the supply bus through circuit No. 4 to the network and back to the supply bus through circuits Nos. 1, 2, and 3 in parallel. The magnitude and phase relations of this current, aside from a possible slight shift in the phase position of network voltage which is ordinarily used as the base of reference, will be determined exactly by the phasing voltage before closing divided by the total impedance around the above mentioned circuit. This relation holds regardless of just what the phasing voltage may be or how it is produced. If it is produced purely by the load current, the circulating current will be subtractive with respect to the load currents existing in circuits Nos. 1, 2, and 3—*i. e.*, will reduce the load currents in these circuits.

If the transformers all have the same impedance phase angle and if, as assumed above, the line conductor impedance is negligible in comparison with the transformer impedance, the line current which flows in each network unit after closing will lag behind the phasing voltage which existed before closing by an angle almost exactly equal to the impedance angle of the transformers

Next, consider Fig. 3 (a) which represents phase-angle conditions for a simple watthour-meter type of relay with controlling currents and voltages impressed either directly upon the relay circuits or through transforming devices which do not change the phase angles. For simplicity, in this diagram relay adjustments for a definite amount of voltage required for closing and a definite amount of current required for opening have been neglected. The network voltage *E N* is the base line of reference. The semicircle to the right of the vertical line represents the range of phase angles of voltage impressed on the phasing circuit of current flowing in the current circuit, throughout which range closing torque will be produced in the relay. The semicircle to the left of the vertical line represents a similar range of phase angles throughout which opening torque will be produced. If voltage drop produced by load current alone is responsible for the voltage impressed upon the phasing circuit before closing, the phase angle of this voltage will ordinarily be somewhat as represented by the vector *E P* in Fig. 3 (a), and if we neglect line conductor impedance, the current after closing will have a position as indicated by the vector *I*, lagging behind the voltage *E P* by an angle equal to the impedance phase angle of the distribution transformers. Both of these vectors give closing torque with the result that the circuit breaker will close and will stay closed causing the transformer bank to which it is connected to take up its proper share of the system load.

The voltage difference before closing, however, may not be produced entirely by load current. If, for instance, it should be determined mainly by regulator positions, there are possible conditions under which it might take the position indicated by the vector *E P* in Fig. 3 (b). In this case the current after closing would take the position shown by the vector *I*, lagging

behind the voltage $E\ P$ by the same angle as before. But in this case the current would fall in the semicircle of opening torque and the result would be that the circuit breaker would close and immediately open again, repeating this operation indefinitely as long as the system conditions remained unchanged. This action, which is called "pumping," would be undesirable not only due to the fact that it might cause objectionable fluctuations of network voltage but also because of the wear and tear on the apparatus itself. In fact, in some designs of network apparatus, this action would cause the burning out of the closing coil of the circuit breaker.

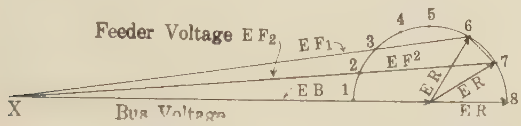

FIG. 4—VECTOR DIAGRAM SHOWING POSSIBLE PHASE RELATIONS OF VOLTAGE DIFFERENCE BETWEEN PRIMARY FEEDERS PRODUCED BY DIFFERENT POSITIONS OF INDIVIDUAL POLYPHASE INDUCTION FEEDER

Phase Position of Phasing Voltage. Fig. 4 represents phase conditions produced by polyphase regulators in individual network feeders. The series regulator voltage is represented by the vector $E\ R$ which revolves with O as an axis and which may take any position along the semicircle as indicated, for instance, by the points 1, 2, 3, 4, 5, 6, 7, and 8. The feeder voltage represented by $E\ F$ may take the positions X-1, X-2, X-3, etc., depending upon the position of the series regulator voltage $E\ R$. The network relay phasing voltage, neglecting voltage drop produced by load current, is the difference between the feeder voltage of the feeders which are in service and that of the feeder that is being connected to the network. This voltage difference may therefore take the positions 1-2, 2-3, 3-4, 4-5, 5-6, etc., depending upon the settings of the regulators in different feeders. In systems having individual feeder regulators of the polyphase type, not mechanically interlocked, therefore, it is possible under conditions of zero load for the phasing voltage to take almost any phase position in the 360-deg. circle of Fig. 3. The position 6-7, for example, is approximately the same as the position of the phasing voltage in Fig. 3 (b), which position would cause pumping in the case of relays with simple watthour-meter characteristics.

The action of single-phase regulators is different from that of polyphase regulators since in the former the phase position of the series voltage is fixed and regulation is accomplished by changes in its magnitude. When each phase of an individual feeder is controlled by a single-phase regulator, therefore, the network relay phasing voltage as determined by regulator positions has a fixed phase relation with respect to the bus voltage. In the case of systems using two single-phase regulators connected open delta, however, the voltage of one of the three phases of a feeder may shift in position if the two regulators do not at all times maintain the same respective amounts of bucking or boosting voltage. Referring to Fig. 5 (a), the triangle $A\ B\ C$ represents the station bus voltage of a three-phase system. The vectors $E\ R$ represent series regulator voltage. These vectors maintain the same phase positions but may vary in magnitude. The feeder voltage of the phase $B\ C$ may take any position with a point in the line $X\ Y$ as one terminus and a point in the line $M\ N$ as the other terminus. These conditions are represented in a somewhat different manner in Fig. 5 (b). The station bus voltage is represented by the line $O\ X$ and the feeder voltage may take any position from point O to any point within the area bounded by the parallelogram. As in the case of polyphase regulators, this system of regulation may, under conditions of zero load, produce a relay phasing voltage of any phase position. As an example, the two positions of feeder voltage shown in Fig. 5 (a) will produce a phasing voltage in approximately the same position as that indicated in Fig. 3 (b). Figs. 1 and 2 represent the position of this phasing voltage in both (a) and (b) of Fig. 5.

Since some load current is nearly always present in a

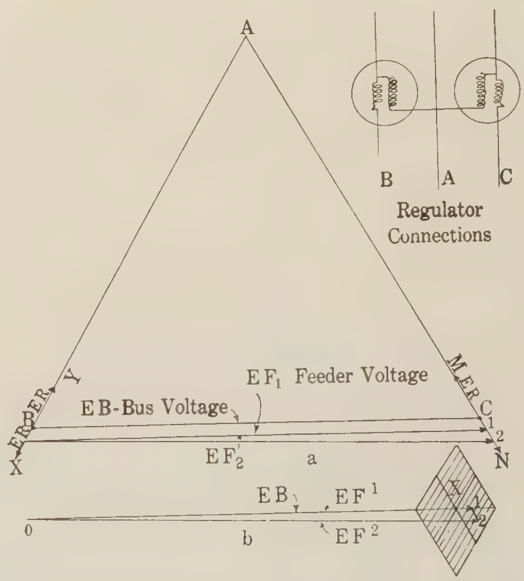

FIG. 5—VECTOR DIAGRAM SHOWING POSSIBLE PHASE RELATIONS OF VOLTAGE DIFFERENCE BETWEEN PRIMARY FEEDERS PRODUCED BY DIFFERENT POSITIONS OF INDUCTION FEEDER REGULATORS CONNECTED OPEN DELTA

network system, the regulators will hardly ever be the sole determining factor of the phasing voltage. If the voltage difference produced by the regulators, however, is greater in magnitude than that produced by load current, and if the former voltage difference can take any phase position in the 360-deg. range, the vector sum of the two voltage differences can also take any position within the complete circle. During heavy load periods it is unlikely that the voltage difference produced by regulators will be greater than that produced by load

current, unless, due to some failure of the control equipment, the regulators should assume considerably different positions. During very light load periods, however, the regulator voltage difference may possibly predominate. Assuming, for instance, that the control equipment of each regulator is set to hold the voltage within a range of two per cent above or below normal, there might easily occur a condition in which the voltage of all but one feeder would be nearly two per cent low and that of the remaining feeder would be nearly two per cent high. This voltage difference of nearly four per cent would be practically equivalent to that produced by between 20 per cent and 40 per cent normal full load in a system having 10 per cent reactance transformers and cables of comparatively small impedance. It sometimes may be difficult to constantly maintain the settings of automatic regulator control equipment within as close limits as two per cent, high or low, and any increase in this value due to wear and tear on the control contacts or other causes will of course cause a proportionate increase in the voltage difference which may be produced by the regulators. Thus in cases

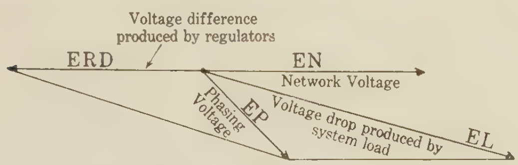

Fig. 6—Possible Phase Relation of Phasing Voltage Produced by Single-Phase Regulator Voltage Difference in Combination with Voltage Drop Produced by Heavily Lagging Load Current

where polyphase regulators or open-delta-connected, single-phase regulators are used and where these regulators are not mechanically interconnected or other special provisions made, pumping may occur during light load periods if the relays have simple watthour-meter characteristics.

In cases where a single-phase regulator controls each separate phase of a polyphase system, although the voltage difference produced by the regulators has a practically fixed phase relation, this voltage in combination with the voltage drop produced by system load may produce a phasing voltage of varying phase positions. Fig. 6 illustrates a somewhat theoretical case which would cause pumping in a relay of simple watthour-meter characteristics. The voltage drop $E\ L$ is that produced by a load of extremely low power factor lagging. The voltage difference $E\ R\ D$ is produced by a lower regulator setting of the feeder which is being connected than that of the feeders which are in service. The resultant of these two voltages is a phasing voltage $E\ P$ in approximately the same position as indicated in Fig. 3 (b). This is a possible condition although it is not likely to occur in practise. A load current which would be sufficiently lagging to produce the conditions illustrated would in all probability be a local concentrated load and not the general load of the system. Its effect would, therefore, be confined to a very few relays.

So far as regulators are concerned, the phase position of the phasing voltage for any system of regulation can be held in a fixed position merely by mechanically interlocking the rotors of regulators in the same phase of different feeders, or, in the case of open-delta connection, by interlocking the rotors of the two regulators of each feeder. Bus or group regulation might also be used, but some engineers do not consider this permissible because of the question of reliability of service which is involved. A regulator short circuit in this latter case would have a much more serious effect upon service continuity than if individual feeder regulators were used. Even in the case of mechanical interlocking or bus regulation, however, there are certain conditions which may produce a phasing voltage of such phase relations as to cause pumping in relays of simple characteristics. Consider a system having primary voltage sufficiently high to produce a cable charging current correspondingly higher than the transformer magnetizing current. In this case when a station circuit breaker is opened in order to disconnect a network circuit from the system a reverse line current of leading phase position will flow. Thus current will have a phase position somewhat as shown by the vector I in Fig. 3 (b). Now suppose that one or more of the network units is faster in opening than the others. As soon as these units open, their relays will obtain a phasing voltage in the position $E\ P$ of Fig. 3 (b), causing closing torque, and the units will tend to close again. In the meantime the other units may have reached the point of opening, but if they open after the first mentioned units have closed, they will then obtain closing torque in the same manner as the first units, and there may be set up an action similar to that of a see-saw, depending upon the time characteristics of the different units. Conditions of pumping may also be produced in a system of this kind in case one or more of the units should, due to some defect, entirely fail to open when the station breaker is opened.

Relay Phase-Angle Characteristics. In view of the above considerations, it appears that network relays of simple watthour-meter phase-angle characteristics impose certain limitations of design upon the remaining portions of the network system if pumping is to be positively avoided. Before this point is discussed further, however, it may be well to consider briefly what the characteristics of a network relay should be in order to make it universally applicable to network systems of varying characteristics.

Consider first the opening operation. Since the unit may be required to open in case of a small reverse line current either leading or lagging, depending upon whether cable charging current or transformer magnetizing current predominates, and since it may be required to open at very large values of reverse short-

circuit current lagging, it is desirable that opening torque be produced by all phase angles of line current within a semicircle extending 90 deg. on each side of the reverse position of network voltage. See Fig. 7 (a).

Next consider the closing operation. In view of the above described relation between phasing voltage and line current, it is desirable that closing torque be produced by all phase angles of phasing voltage within a semicircle generally opposite to the opening sector but shifted in a leading direction with respect to the vertical line which defines the latter by an angle ϕ equal to the impedance angle of the distribution transformer banks. If an angle greater than this is used, troubles from pumping may be encountered due to too great an overlapping of the characteristics in the upper part of the diagram. See Fig. 7a.

In the discussion of the relation between phasing voltage and line current, it was assumed that line conductor impedance is negligible in comparison with transformer impedance. This is only approximately correct for high load density underground systems in which the transformer installations have high reactance,—say

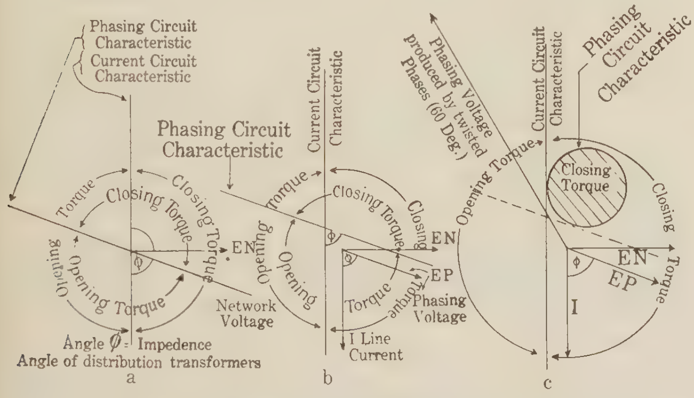

Fig. 7—Vector Diagram Illustrating Desirable Phase Angle Characteristics of Network Relays

10 per cent. It is not even approximately correct in many systems having transformers of standard impedance. In the latter systems, therefore, unless the line impedance angle is equal to the transformer impedance angle, the phase angle ϕ between phasing voltage and line current is not a fixed quantity but will vary with varying system load, different numbers of feeders in service, etc. In addition to the other advantages of high impedance in the transformer installations, therefore, there is the possible advantage of increased stability of operation of network relays due to the approximately fixed relation between phasing voltage and line current.

In a relay of this kind, reasonably small variations in the system impedance angle and also small differences between the relay phase angle and the basic phase angle of the system are rendered harmless by shifting both the straight line representing closing torque and that representing opening torque away from the zero point of the polar diagram as shown in Fig. 7 (b). This shift corresponds to the relay settings for a definite amount of phasing voltage necessary to close, and a definite amount of line current necessary to open, the diagram Fig. 7 (a) being for settings representing zero values of these quantities.

So far the requirements for locking the unit open in case of twisted phase relations of line conductors have not been considered. The characteristics shown in Fig. 7 (b) do not entirely conform to the requirements for preventing a closure under twisted phase conditions. For example, if the transformer which is to be connected to the network should have its connections twisted so as to obtain a voltage leading the network voltage by 60 deg., the resultant phasing voltage would fall within the closing sector and if the other relays of the network unit should obtain torque in the same direction the result would be the equivalent of a system short circuit. This possibility would be very remote especially in systems where it is the usual practise to phase out the line conductors before making a connection. Trouble from this source could be entirely prevented, however, by the use of relays having characteristics similar to those shown in Fig. 7 (c). The closing characteristic, instead of being represented by a straight line, is bounded by a curved line which bends back on itself and forms a complete circuit. Phasing voltages of such angles and magnitudes that the terminals of the vectors representing them would fall within the area bounded by this curved line would cause closing action. Voltages the vectors of which would fall outside of, or completely cross, this area would not cause closing action; that is, phasing voltages of large magnitude, no matter what their phase angles might be, would lock the unit open. A relay of these characteristics would have several advantages: With the characteristics shown in Fig. 7 (b) a certain range of phase-angle adjustment would be necessary to conform to distribution systems of different phase angles. With the characteristic shown in Fig. 7 (c) a very wide range of system phase angles could be allowed without the necessity of changing the relay phase angle.

There would also be the advantage that if at some time in the future the development of a-c. networks should require the feeding of a system from separate generating sources and if it should be found practicable to synchronize the generating sources through the network, the synchronizing might be accomplished automatically by relays of this type, assuming that the proper time characteristics could be developed. A design which would produce the characteristics shown in Fig. 7 (c) is theoretically possible with relatively simple construction and somewhat similar characteristics have been produced experimentally.

Future Development

In the preceding discussion, as well as that which follows, it is of course understood that by "relay characteristics" is meant the combined characteristics of the

relay and its associated circuits and transforming devices, since the control of some of the characteristics can be accomplished by altering the constants of the circuits external to the relay.

Relays of the ideal characteristics described above have not yet been given the test of actual service. The design of such a relay, while it need not be unduly complicated, would, of course, partake more of a special nature than that of a simple watthour-meter type of relay or than that of the modified watthour-meter types which are now in commercial production. It is apparent from the above discussion that if relays of simple characteristics are used, certain limitations are placed upon the design of the remainder of the distribution system and provisions must be made in the latter to insure successful operation. For instance, a system having mechanically interlocked regulators, or possibly having single-phase regulators in each phase without mechanical interlocking, and having a primary voltage sufficiently low to insure that the transformer magnetizing current would predominate over the primary cable charging current, could ordinarily be expected to operate without pumping, with relays of simple watthour-meter characteristics. The provision concerning primary voltage might not be considered necessary by some engineers, particularly if the relays were designed so as to require considerably less time for the opening operation than that required for the closing operation. This design characteristic would tend to prevent the see-saw action described above, but would not prevent pumping in case of the failure of one or more units to open when the station breaker is opened. The latter action might not be serious if precautions were taken in the operation of the system to insure that the station breaker would not be left open for any appreciable length of time in case of a "feed back." There are also, of course, other expedients which could be used to minimize the effects of high cable charging current, such, for instance, as the use of reactive loading coils to add lagging current to the primary feeders.

The simple type of relay has the advantage of a probable lower cost, due to the fact that most of the parts used in its construction may be standard for other similar apparatus. It also has the advantage of less complications in the electrical circuits. Neither of these advantages should be given undue importance since the design of the ideal type of relay need not necessarily be excessively complicated. The simple type of relay has the disadvantage that special provisions possibly involving additional cost and operating disadvantages may be required in the design of the remaining portions of the distribution system.

In the future development of this apparatus, therefore, there is a choice to be made between simplicity of relay characteristics involving possible additional cost and operating disadvantages in the remainder of the system, and comparative complexity of relay characteristics involving possible additional cost and complications as regards the relays and associated devices, a compromise solution being the use of simple relays in combination with relays of twisted phase angles or other special characteristics.

It seems reasonable to suppose that the ultimate trend of development will be toward standardization upon either a simple type of relay or upon one of ideal characteristics of universal application. What the trend of this development will be is not apparent from the present state of the art. It will be determined to a large extent by future operating experience, with existing types of relays and network systems, and upon the future development of the latter, such, for instance, as the possible interconnection of separate generating sources through network distribution systems. In the meantime, close cooperation between the relay designing engineer and the distribution engineer is necessary in order to insure that the characteristics of the present types of relays will fit those of the distribution system and vice versa.

In conclusion, the writer gratefully acknowledges the assistance of Messrs. A. H. Kehoe, C. W. Franklin, G. R. Milne, D. K. Blake, and J. S. Parsons, in examining and criticizing the first draft of this paper. The writer also wishes to call attention to the fact that engineers of the United Electric Light & Power Co. of New York, the Palmer Electric Mfg. Co., The Westinghouse Electric & Mfg. Co., and more recently, the General Electric Co., have been largely responsible for the development of automatic network protective apparatus to date, the writer having had the good fortune to be associated at times directly, and at other times indirectly, with several of these engineers in this development.

Conclusions

1. Due to the combination of a number of different control requirements in one piece of apparatus, the interrelations between the various actuating forces of automatic network relays are somewhat complicated, although the construction and adjustments of the relays themselves may be quite simple.

2. Important factors in the operating requirements as to relay characteristics are the impedance phase angle of the distribution transformers; the phase angle and magnitude of the impedance of primary and secondary line conductors; the relation between the magnitude of line charging current and that of transformer magnetizing current; and the particular type of voltage regulation which is used for the primary feeders.

3. Relays of present commercial design are not universally applicable to all the different physical characteristics of network systems which might be used in practise. There must be close cooperation, therefore, between the distribution engineer and the relay designing engineer in order to insure the correct functioning of the individual distribution system as a whole.

4. A network relay of such characteristics as to be universally applicable to all distribution system characteristics which might ordinarily be encountered would involve somewhat greater complications in design and possibly somewhat greater cost than a relay of simple watthour-meter characteristics. In the future development of network relays, therefore, there is a choice to be made between simple relay characteristics with the corresponding limitations on distribution system design, on the one hand, and universally applicable relay characteristics with the corresponding complications in relay design, on the other hand, a compromise solution being the use of simple relays in combination with relays of special characteristics. The future trend of development will probably be toward one or the other of the first two mentioned solutions. This trend will be determined, to a large extent, by future operating experience with existing types of relays and by the trend of development of network distribution as a whole.

Abridgment of

Radio Broadcast Coverage of City Areas

BY LLOYD ESPENSCHIED[1]

Member, A. I. E. E.

Synopsis—*1. Radio broadcasting involves a system of electrical distribution in which dependent relations exist between the transmitting station, the transmitting medium and the receiving station.*

2. The attenuation and fading which attend the spreading out of broadcast waves are considered. The attenuation of overland transmission is shown to be, on the whole, very high and to vary over a wide range depending upon the terrain which is traversed. The distance at which the fading of signals occurs is found to be that at which the normal directly transmitted waves have become greatly attenuated and to depend upon the terrain traversed.

3. A field strength contour map is given of the measured distribution of waves broadcast by station WEAF over the New York metropolitan area. A rough correlation is given between measured field strengths and the serviceability of the reception in yielding high grade reproduction. The range of a station as estimated in terms of year-round reliability is found to be relatively small. It becomes clear that the present radio broadcasting art is upon too low a power level and that higher powered stations are required if reliable year-round reception is to be had at distances as short even as 30 to 50 from the transmitting station.

4. The question of the preferred location of a transmitting station with respect to a city area is considered. It is shown that an antenna located upon a tall building may radiate poorly at certain wavelengths and well at others. Surveys are presented of the distribution effected by an experimental transmitting station located in each of several suburban points. The locations are compared upon the basis of the "coverage" of receiving sets which they effect.

5. Finally, there is considered the relation which exists in respect to interference between a plurality of broadcast transmitting stations operating in the same service area. The importance of high selectivity in receiving sets is emphasized and there is given the measured selectivity characteristics for samples of a number of receiving sets.

It is well recognized that the elements which comprise an electrical transmission system are required to function not simply as individual pieces of apparatus, but as integral parts of a whole. In the case of radio broadcasting, the absence of a common control of the two ends makes this over-all "systems" aspect less apparent than it is for wire systems.[2] Nevertheless a definite systems correlation is required between the broadcast transmitting station and each of the receivers served, as will be evident from the following:

1. The transmitter should put into the transmitting medium, without distortion and with the power called for by that medium, all of the wave-band components required and no others.

2. The transmitting medium should be capable of delivering to the receiver an undistorted wave band, reliably and stably, and with sufficient strength to enable the received waves to stand well above the level of the ever present interfering waves.

3. Finally, the receiving set should pass with the necessary volume all of the wave components required to reproduce the program signal and should sharply exclude all others.

The rapid apparatus development borne in by the vacuum tube has brought the art to the point where it is now physically possible to meet quite fully the terminal requirements. The apparatus development, in fact, has outstripped our knowledge of the transmitting medium itself, and we are now in the position of possessing apparatus possibilities without knowing very definitely the limitations and requirements placed upon their use by the intermediate link. Only within the last few years have methods become available for measuring radio transmission and thereby placing it upon a quantitative basis.

It is the purpose of the present paper to present results of a systematic study which has been made of the coverage which can be effected of the radio broadcast listeners of the New York metropolitan area and in so

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1. Dept. of Dev. and Research, Am. Tel. and Tel. Co., New York, N. Y.

2. Some other examples of such a "systems" relationship are given in "Application to Radio of Wire Transmission Engineering," published in the *Proceedings* of the Institute of Radio Engineers, October, 1922.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

doing to portray something of the general systems requirements of radio broadcasting.

The Character of Radio Broadcast Transmission

The ideal law for broadcast distribution would be one whereby the transmitted waves are propagated at constant strength over the zone to be served and then fall abruptly to zero at the outer boundary.

The kind of law which nature has actually given us involves a rapid decadence in the strength of the waves as they are propagated over the service area, and then, instead of a sharp cutoff, a persistance to great distances at field strengths which, although often too low to be generally useful, are sufficient to cause interference in other service areas.

Recent researches make it seem clear that radio transmission involves wave components of two types: One which delivers directly to the receiving area immediately surrounding a broadcast station a field capable of giving a reliable high grade reception; and another transmitted through the higher altitudes which permits distant reception but not with the reliability and freedom from interference required of high grade reproduction.

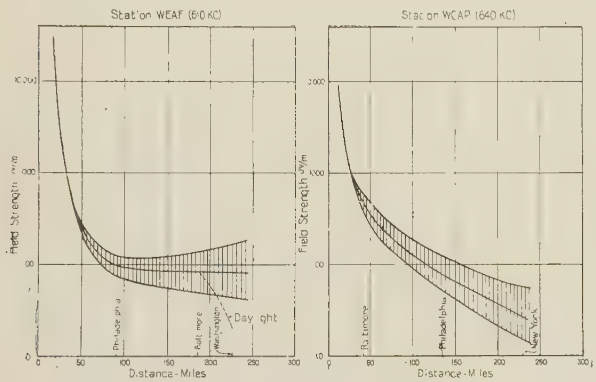

Fig. 2—Results of a Few Measurements upon the Reduction in Field Strength with Distance, Including Distances at Which Fading Occurs

The effects which are actually realized in practise are indicated in a more quantitative manner by the curves of Fig. 2 which are plotted from some measurements made upon WEAF in New York and WCAP in Washington, D. C. They were made at locations in the New York and the Washington areas and at the intermediate points indicated on the curves. The measurements at each of these points are for one day only. The day and night fields were found to be roughly the same except for WEAF where there is a material drop in the daytime signal between Baltimore and Washington, shown in the WEAF curve.

Fading was observed to commence somewhere between 50 and 100 mi. from the stations and the range of the fluctuations was found to increase up to the maximum distance observed. That the field of WEAF was found to be practically as strong at Baltimore as at Philadelphia is surprising. The data regarding this point are too meager, however, to permit any very definite conclusions to be drawn. The curves are useful principally in enabling the transition to be followed, in a more quantitative way than is done in Fig. 1, from field strengths capable of giving reliable reception, such, for example, as 10,000 μ v per m., to those which characterize the unreliable "distance" reception and are of the order of 100 μ v per m.

A fact which is of importance to our understanding of these wave phenomena is that "fading," which ordinarily is noticed at distances of the order of 100 mi., may under some conditions become prominent at distances as short as 20 mi. from the transmitting station. Such short-distance fading has been experienced in receiving WEAF in certain parts of Westchester County, New York[3]. It appears to be a case where unusually high attenuation, caused by the tall building area of Manhattan Island, has so greatly weakened the directly transmitted wave as to enable the effect of the indirect wave component to become pronounced at night. In general, the attenuation suffered by the normal surface-transmitted waves varies over wide limits depending upon the terrain which is traversed.

Actual Distribution in New York City

Fig. 4 presents the results of a detailed survey of the field distribution effected over the New York metropolitan area by station WEAF located at 463 West Street. The measurements upon which the plot is based were taken in the daytime during the summer of 1925. Measurements were taken at approximately one-mile intervals along each of a series of circular paths concentric with the station, the radii of which increased in steps of approximately five miles. The distribution was studied in even greater detail close to the station and in locations giving evidence of rapid change in field strength. The plot is based upon over 1000 measurements. While these measurements were taken over a considerable period of time, check measurements proved conditions to have remained quite stable and showed, in fact, little variation from measurements made the previous year. The type of measuring apparatus employed, together with certain of the results obtained in earlier surveys, has already been described[5].

The fact previously referred to, that the waves transmitted into Westchester County experience high attenuation, is shown by the shape of the contour lines.

A question which naturally arises is that of how strong a field, as measured in this way, is required for satisfactory reception. It is too early in the art to answer this question very definitely, for it depends first

3. See "Some Studies in Radio Broadcast Transmission," by Ralph Bown, D. K. Martin and R. K. Potter; *Proceedings*, I. R. E., Feb. 1926.

5. See previous reference; also "Portable Receiving Sets for Measuring Field Strengths at Broadcasting Frequencies," by Axel G. Jensen, *Proceedings*, I. R. E., June, 1926.

upon the standard of reception which is assumed, with respect to quality of reproduction and freedom from interference; and second upon the level of the interference. The interference, both static and man-made, varies widely with time and with location. It is therefore obviously impossible to give anything more than a very general interpretation of the absolute merit of field strength values. Observations made by a number of engineers over a period of several years in the New York City area, having in mind a high standard of quality and of freedom from interference, indicate the following[6]:

1. Field strengths of the order of 50,000 or 100,000 μv per m. appear to be about as strong as one should ordinarily desire. Fields much stronger than this impose a handicap upon those wishing to receive some other station.

2. Fields between 50,000 and 10,000 μv per m. represent a very desirable operating level, one which is ordinarily free from interference and which may be expected to give reliable year-round reception, except for occasional interference from nearby thunder storms.

3. From 10,000 to 1000 μv per m. the results may be said to run from good to fair and even poor at times.

4. Below 1000 μv per m. reception becomes distinctly unreliable and is generally poor in summer.

5. Fields as low as 100 μv per m. appear to be practically out of the picture as far as reliable, high quality entertainment is concerned. Such fields, however, may be of some value for the dissemination of useful information such as market reports, where the value of the material is not dependent upon high quality reproduction.

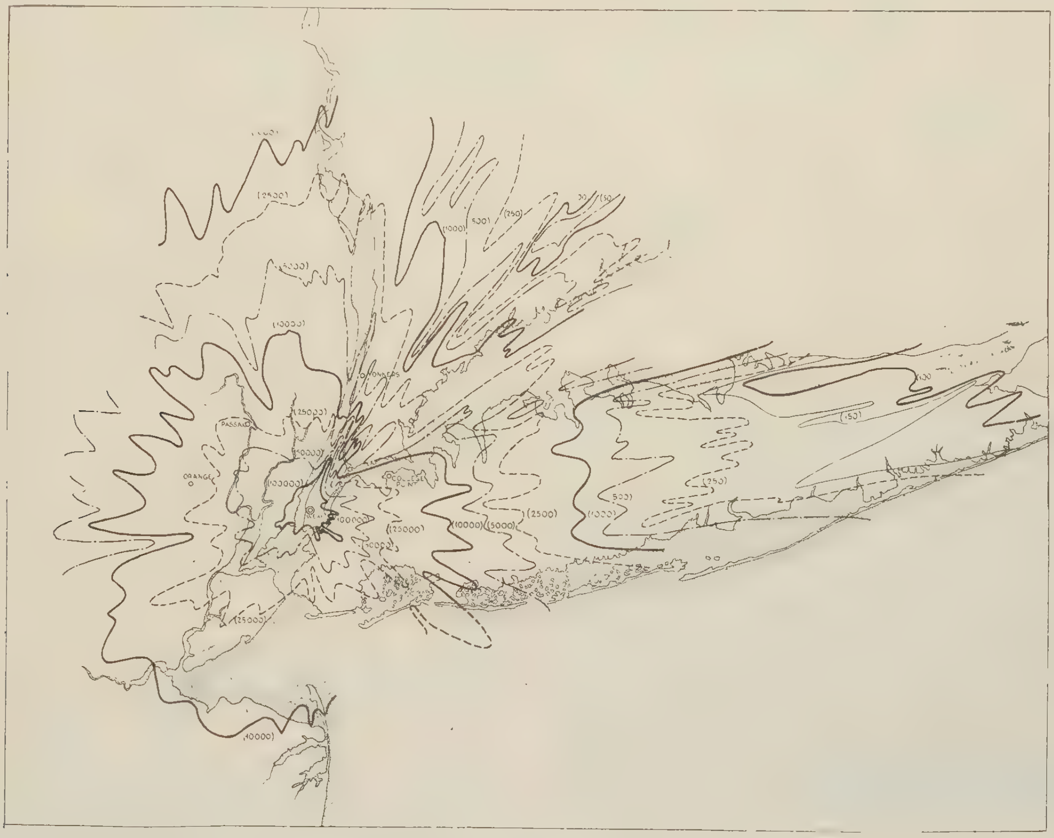

Fig. 4—Field Strength Contour Map of Distribution over the New York Metropolitan Area, Effected by Station WEAF

(5 kilowatts in antenna, frequency 610 kilocycles, wavelength 492 meters)

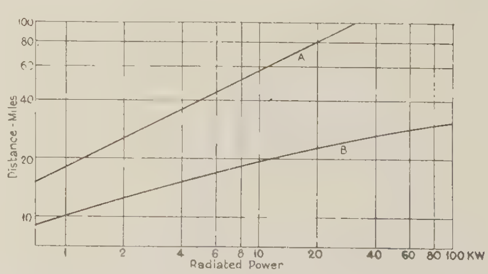

Fig. 5—Showing the Increase in Radiated Power Required to Increase the Range at which a Field of 10,000 μv/m is Delivered

Curve *A* without absorption and Curve *B* with absorption

It is seen from the preceding three figures that a 5-kw. station may be expected to deliver a field of 10,000 microvolts some 10 to 20 mi. away and a 1000-microvolt field not more than 50 mi. From this it will be evident that the reliable high quality program range

6. See also the paper by A. N. Goldsmith, "Reduction of Interference in Broadcast Reception," *Proceedings*, I. R. E., October, 1926.

of a 5-kw. station is measured in tens of miles rather than hundreds.

Higher Power Transmitting Stations Required

Rough though this interpretation of field strengths is, it indicates clearly the need which exists for the employment of higher transmitting powers. The range goes up with the increase of power disappointingly slowly. Even were no absorption present in the transmitting medium, the range in respect to overcoming interference would increase only as the square root of the increase in power. This is shown in the curve A of Fig. 5. It shows that a station which actually radiates five kw. of power would deliver a 10,000 $\mu \frac{v}{m}$ field at about 40 mi., a 20-kw. station the same field at distance 80 mi. Actually with absorption present the distances are less. This is shown by the curve B which gives the corresponding relations for the absorption observed for suburban and country terrain. To extend the 10,000-microvolt field from some 15 mi. out to 30 mi. would necessitate an increase in the radiated power from about five to 100 kw.

Fig. 7—Transportable Field Transmitting Station

It is apparent from these relations that radio broadcasting is today underpowered; that the common 0.5-kw. station is entirely too small to serve large areas adequately, and that the more general use of powers of the order of five kw. and even 50 kw. is decidedly in order.

Distribution from Suburban Locations

In order to determine the distribution over New York City which might be effected from locations outside of Manhattan Island, experimental transmitting stations were established at each of several suburban locations. Use was made of an automobile truck equipped with a ½-kw. broadcast transmitter and provided with a transportable mast. The experimental transmitter as set up at Secaucus, N. J. is shown in Fig. 7. Measurements of the field strength delivered from each of the locations chosen were made over practically the entire metropolitan area. The results of these tests are given in Fig. 8, in comparison with those of transmission from the normal location of WEAF at West Street and from the earlier location at 24 Walker Street. The measured field strengths have been adjusted to correspond to the 5-kw. transmitter of the West Street station.

The smaller irregularities in the West Street curve as compared with the others are due to the greater detail with which these measurements were made. The curves should be compared merely with respect to their major contour characteristics. The inner contour line is for 50,000 μ v per m. and the outer line for 10,000 μ v per m. Actually, the measurements were made in sufficient detail to enable other contour lines to be drawn but these have been omitted for the sake of simplicity.

The radiation from Secaucus will be seen to deliver a strong field to Manhattan Island, the most densely populated section and, in general, to encompass the rest of the city quite well within the 10,000-μ v. line. The irregularity in Queens County evidently represents the shadow cast by the tall building area on Manhattan Island.

The distribution effected from the College Point location appears to be generally good. It does not cover the New Jersey suburbs as strongly as might be desired. The shadow cast by the Manhattan Island high buildings lies through Jersey City and lower Newark.

The distribution from the West Orange site appears to be somewhat less favorable. It is not sufficiently close in to deliver with moderate power a very strong field to the center of the population, nor is it sufficiently far out to avoid subjecting a considerable population in the immediate vicinity of the station to an excessive field were high power employed. The indent in the 10,000-μ v. line in northern Queens is the shadow of the Manhattan buildings.

The distribution shown for the Walker Street location is seen to be generally similar to that of West Street. The curve presents a smoother appearance than the others because less data were taken in this one of the earlier surveys. The shadows cast to the north and to the south by the two areas of high buildings are prominent. Actually, a close examination of the contour lines reveals a noticeable angular displacement in the Westchester shadow as between Walker Street and West Street, Walker Street transmitting better up the Sound and West Street better up the Hudson. West Street turns out to be somewhat the better of the two.

The last diagram of the series brings together the shadows as determined from the several transmitting sites and shows that they project back to a common general center which locates at approximately 38th Street and Broadway, which corresponds quite well with the center of the up-town tall building center.

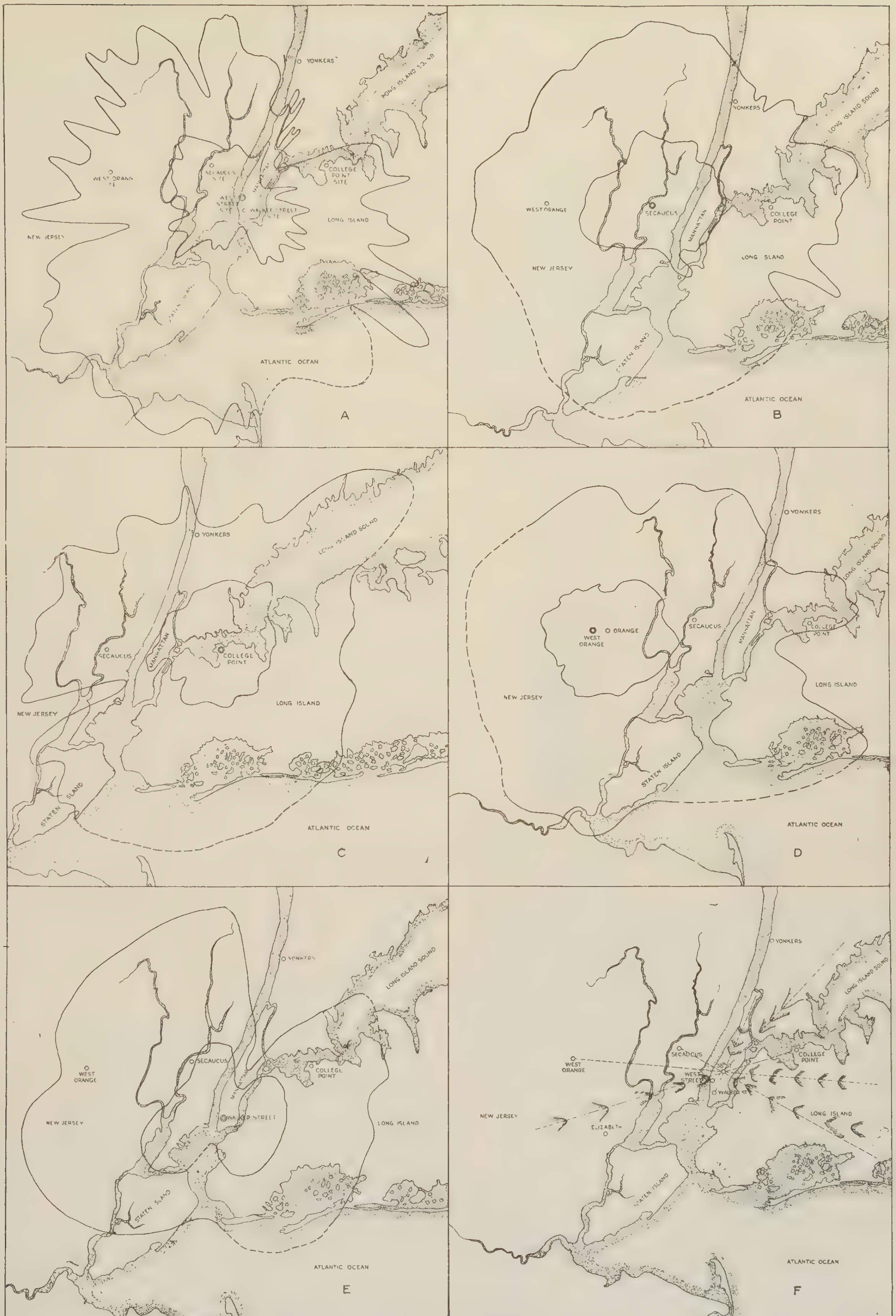

FIG. 8—EFFECT UPON THE FIELD DISTRIBUTION OF MOVING THE TRANSMITTING STATION TO SUBURBAN LOCATIONS

A—463 West Street, New York City
B—Secaucus, N. J.
C—College Point, Long Island, N. Y.
D—West Orange, N. J.
E—24 Walker Street, New York City
F—Composite figure showing main shadows and center of obstacle

Relation Between Wave Distribution and the Distribution of Listeners

The merit of a given distribution pattern obviously depends upon the relation which exists between it and the distribution of the receiving sets themselves. In order to study this relation more closely, the relative distribution of receiving sets was approximated by taking the distribution of residence and apartment house telephones in each of the central office districts of the metropolitan area, excluding the commercial telephones. It was assumed that the receiving set distribution is proportional to that of the telephones. For a given survey the field strength representative of each central office district is known. By assembling the figures for central office areas receiving like field strengths, and by doing this for the whole range of field strengths measured, an accumulative percentage curve may be derived which shows the percentage of the total number of receiving sets included within the contour lines of successively weaker fields.

Curves of this kind for each of the several surveys

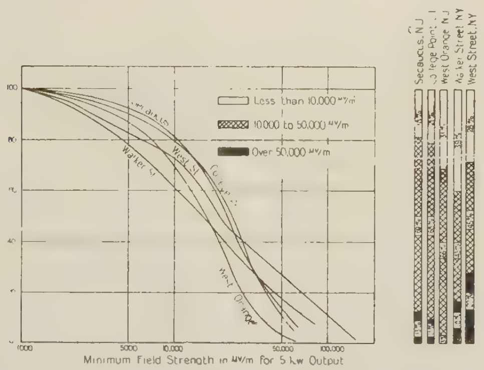

Fig. 9—Percentage of Receiving Sets in Metropolitan Area Included Within Various Strengths of Field for Each of the Transmitting Locations of Fig. 8

made are shown in Fig. 9. It will be seen that for field strengths of 10,000 μ v per m. and better, the Secaucus and College Point transmitting sites include about 80 per cent of the receivers, that the West Street and West Orange sites include around 70 per cent and Walker Street about 60 per cent. These curves are further analyzed in the chart to the right of the figure to show in each case the proportion of the listeners which may expect to receive

a. less than 10,000 μ v per m.
b. between 10,000 and 50,000 μ v per m.
c. over 50,000 μ v per m.

It is seen from this that a location to the east or west of Manhattan Island would give a material improvement in uniformity of distribution as compared with a location on Manhattan Island. Had it been possible to include a station on Manhattan Island located farther north then is either West Street or Walker Street and included within the area of high steel buildings, it is probable that the corresponding curves for such a location would show the poorest distribution of the series.

The survey work described above did not go so far as to include a study of the distribution effected from a location well outside of the suburbs. The philosophy of such a location is, of course, that of attempting to encompass within the range of the station a wide-spread area and of so including the city within the area as to effect a more uniform distribution over it than is possible when transmitting from a location within the city. A theoretical study was made of the distribution to be effected from one such location in the general vicinity of Boonton, N. J., using attenuations obtained in the other surveys. Such a location would be somewhat similar to that of WJZ at Bound Brook, although the distance from Boonton to New York is less. The figures derived upon the basis of a 50-kw. broadcasting station are as follows:

Field Strength	Percentage of Receiving Sets in Metropolitan Area
Below 10,000 μ v per m.	10 per cent.
Between 10,000 and 50,000 μ v per m.	79 per cent.
More than 50,000 μ v per m.	11 per cent.

Receiving in Apartment Houses

The surveys described above disclose the field strength distribution as measured generally in the streets and open places. It does not disclose the details of field distribution in the immediate vicinity of a receiver. Perhaps the most difficult situation is that of the large apartment house, particularly where it is desired to receive by means of an indoor antenna.

The results of a few observations upon signal strength reduction within two buildings are presented in Fig. 11. In the case of the steel structure building depicted in Fig. 11, the interior field is found to be reduced to as low as a few per cent of that outside the building. For outside rooms, the field strength near the window was found to be about eight times that further in the room. Such severe shielding effects obviously call for picking up the wave energy outside the building and conducting it to the receiving sets by wire circuits, preferably by shielded circuits, in order to protect against local interference.

Multi-Station Operation

In order to throw some light upon this important factor of frequency selectivity, measurements have been made upon a sample or two of each of a number of different types of radio receiving circuits. The measurements were made in the laboratory[7], simulating as closely as possible the conditions under which the receiving sets would be used. The curves of Fig. 12

7. The method consists in establishing a small laboratory transmitter and modulating it with a single-frequency tone. The receiving set is tuned to the modulated carrier signal as in practise. The gain or sensitivity of the receiver and its coupling with the transmitter are adjusted to produce normal load upon the detector tube. With the receiving set left at this adjustment the frequency of the radio transmitter is shifted each side of the original single frequency in 10-kc. steps throughout a range of 50 to 100 kc. For each of the offside frequencies the reduction caused in the detector output current is measured, this being an indication of the receiving set selectivity.

show the reduction which is to be expected in the detected audio-frequency current, were the receiving set tuned to a transmitting station on 900 kc., and the transmitting station then shifted in frequency by the amounts given along the abscissa. In this curve the reduction in current is indicated both as a ratio and in TU, which is a convenient way of indicating power ratios. The relation between TU's and current ratio with a given impedance is indicated in the figure. Thus, for a carrier transmitted 40 kc. off from the one

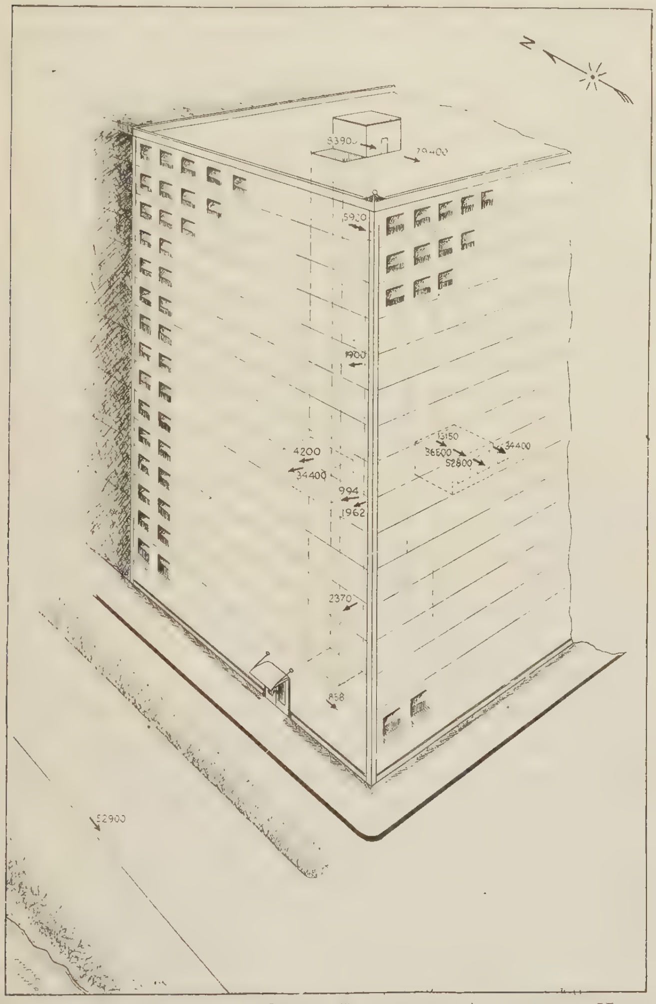

Fig. 11—The Effect of Steel-Structure Apartment House Building in Shielding Radio Reception Within it

to which the set is tuned, the single-circuit, non-regenerative type of receiver showed a cutoff of only 20 TU, corresponding to an audio-frequency current reduction to 0.1 that of value at resonance. The curves will be seen to group themselves more or less into three classes in the order of their selectivity merit as follows:

1. The single-tuned circuit (non-regenerative and regenerative), and the combination of two tuned circuits coupled together.

2. Circuits employing radio-frequency amplification with tuned circuits between stages.

3. The double-detection of superheterodyne type of circuit.

The curve for the double-detection type of circuit shows a "come-back" which represents the familiar double-tuning effect. (Incidentally, this admittance of this particular set, which was not a commercial set, needs to be reduced by the use of more selectivity at radio frequency.)

For comparison purposes there has been added to the figure the curve marked "ideal selectivity characteristic," in accordance with which the receiving set would pass without attenuation all frequencies up to 5000 or 10,000 cycles and would cut off abruptly all frequencies without this band. Attention is first called to the fact that the various circuits attenuate *within* the desired transmission band of five or ten kilocycles. This means the higher frequency components of the side band will be reduced by the amounts indicated (after detection) with corresponding distortions of the reproduction. The distortion will be seen to be greater for the more highly selective sets. This follows from the

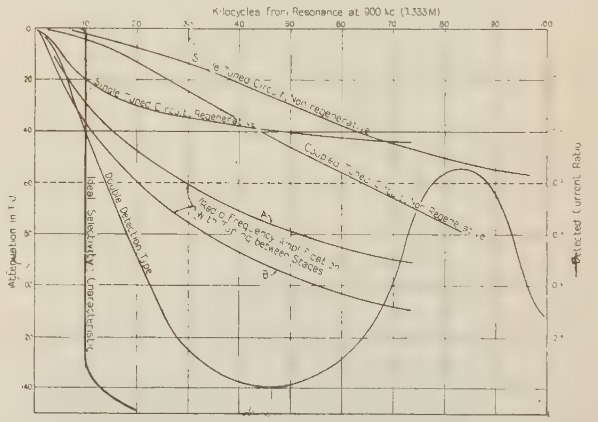

Fig. 12—Receiving Set Selectivity Characteristics as Measured from Samples of Receivers Having Different Types of Selective Circuits

nature of sharply tuned circuits. Selective circuits, capable of approximating the filter type of characteristic, are to be desired.

In comparing these selectivity characteristics, it is necessary to have in mind the amount of differentiation between the desired and the undesired signal which is necessary for the avoidance of interference. Each of the signals may be considered as fluctuating during the rendition of the program over a considerable range of volume which centers about some average value. The amount of differentiation required between the average values obviously depends upon the range of the fluctuations involved and upon the standard which is assumed with respect to freedom from interference. Experience with loud speaker reproduction indicates that ordinarily a level of the average of the undesired signal 40 TU lower than that of the desired signal, while not giving noticeable interference at times when the desired signal is strong, does permit the undesired signal to "show through" during times when the program rendition is weak. Reducing the undesired signal to 60 TU below the desired signal prevents this interference for the volume ranges which are now commonly transmitted. If the future art brings with it the requirement of following greater swings of volume, a

further reduction in the undesired signal may be necessary. The value of 60 TU has been dotted in across the chart of Fig. 12, in order to show readily the frequency separation at which the different selective circuits give this attenuation of the undesired signal. This is upon the basis that the field strengths of the two signals are equal. Inequalities in field strength require that the 60-TU value be increased or decreased by the amount of the inequality as measured in TU.

The frequency interval which has been recommended by the National Radio Conferences for stations in the same zone is 50 kc. It is evident from the curves that sets equipped with the simpler types of tuned circuits will be subject to some interference between stations thus separated even if the receiver is so favorably situated as to receive equal field strengths from the desired and undesired stations. The selectivity of the other types of receiving circuits is seen to be sufficient to avoid interference under these conditions and allow some margin for overcoming inequalities between the fields. Such inequality becomes great where the attempt is made to receive distant stations through the effect of local stations.

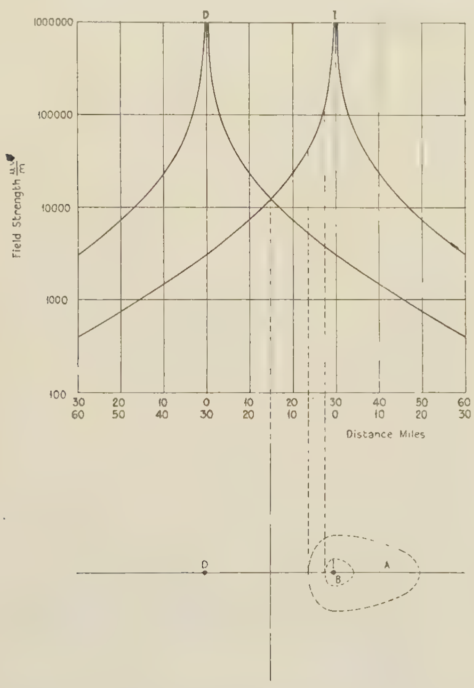

Fig. 13—Showing the Greater Area over Which the More Highly Selective Receiving Sets May Receive a Desired Station D and Exclude an Interfering Station I

The effect of receiving set selectivity in increasing the area over which a station may be received without interference from a second station is illustrated in Fig. 13. The two stations are assumed to be of equal powers so that they deliver equal field strengths to receiving stations along a line midway between them. Receiving sets so located are required to have an amount of selectivity called for by the crosstalk margin itself, say 60 TU. On the desired station side of this line the selectivity may be less; this is the region where poorly selective receivers can be employed. On the undesired-station side of the center line the selectivity requirements are greater. The non-interference area is pushed up closer and closer to the undesired station as the receiving set selectivity is improved, as is indicated by areas *A* and *B* of the figure. For example, assume that the selectivity of the receiving set is such as to give a 100-TU cutoff of an undesired station, offset by 50 kilocycles. Sixty TU of this would be required were the two signals of equal strength, so that 40 TU measures the difference by which the undesired signal may be greater than the desired one. The increased area of reception made possible by this additional 40 TU is indicated by that portion of the lower figure which is to the right of the center line and outside of the area *A*. Within the area *A* interference would be suffered. This interference area may be diminished by the use of still greater selectivity. The addition of another 20 TU of selectivity (again as measured in terms of detected audio-frequency current) would reduce the interference area to that within the small area at *B*. The extent to which the selectivity requirement of the receiving set is determined by its location, therefore, is apparent. The conditions which obtain in multi-station areas, such as New York City and Chicago, obviously call for a general use of high selectivity sets.

In locating a new transmitting station it should be possible from a knowledge of the relative field strengths of other stations in the vicinity to predict approximately what the interference area will be for the different types of receiving sets. In this connection there should be recognized the advantage from the interference standpoint which exists in grouping together the broadcast transmitting stations as far as possible in one location, and in equalizing their powers. Such grouping and equalizing would enable the receivers to obtain substantially equal fields from all of the stations and would minimize the selectivity which they are required to possess. While it is impracticable to accomplish this result completely, it is hoped that a better understanding of the interference problem as here outlined and of the mutual advantage to be gained in reducing interference will lead naturally to a better coordination of radio broadcast stations.

Acknowledgment

The data and analyses presented in this paper are the result of the cooperative effort of a number of engineers in both the American Telephone and Telegraph Company and the Bell Telephone Laboratories, Inc. In assembling and presenting the material the writer is acting merely as the spokesman for these development groups. He wishes to acknowledge his indebtedness to his colleagues, particularly to those who have directly participated in the survey work described and assisted in the preparation of the paper, namely, Messrs. D. K. Martin, R. K. Potter, G. D. Gillett and H. B. Coxhead and to Messrs. S. E. Anderson and O. O. Ceccarini of the Bell Telephone Laboratories to whom is due the measurement work upon the radio receiving sets.

The Lighting of Railway Classification Yards

BY GEORGE T. JOHNSON[1]

Non-Member

Synopsis.—*This paper deals primarily with the illumination of modern large classification yards of the hump type in which the traffic is in one direction. Floodlighting is advocated as the most generally satisfactory system, and various arrangements, to meet the different conditions of yard layout, space available, etc., are described.*

* * * * * *

THE lighting of railway classification yards is a problem of space lighting, the length of yards varying from 3200 ft. to 6500 ft., the width from 400 ft. to 650 ft., and the distance from the hump to the last switch on the ladder, from 1300 ft. to 1800 ft. in our modern yards,—all depending upon the capacity of the yard. The accompanying illustrations show typical layouts of classification yards having four ladder tracks. Ten tracks generally diverge from each ladder track. The space between the ladder tracks is used for the speeder cars which carry the hump riders back to the hump after cars have been brought to rest in the classification yard. In the case of a yard where car retarders are used, this space could be utilized for pole lines carrying a lighting distribution system.

No work other than the classification of cars is performed in the modern classification yard, the air testing and inspection being performed in the departure yard, and consequently there is no necessity for local or intense illumination.

The ladder tracks of classification yards are seldom built on curves; in fact, in yards where retarders are used, the curvature is limited to six deg. Therefore the problem of curved track lighting need not be considered.

There are two adjuncts to a modern classification yard; namely, the receiving yard and the departure yard. No illumination is ordinarily required in these other than that which is necessary for police protection or in cases where short trains are pushed into the receiving yard on the same tracks or diverging tracks, for the storage of previous trains. In some instances, however, where receiving yards are built with considerable curvature, there is an advantage in providing sufficient illumination to enable engine drivers to observe their respective courses.

The tracks connecting the classification and departure yards, covering a distance varying from 400 ft. to 700 ft., require local illumination. The most effective means of providing this illumination is by the angular type of reflector, with the beam of light directed in such a manner as not to affect the vision of the engine driver who is required to cover these tracks and who is frequently unable to obtain the benefit of the locomotive headlight because of the curvature of tracks and on account of switches. With the angular reflectors giving a wide beam, the proper spacing is about 100 ft. for 300-watt lamps at an elevation of 22 ft. above the tracks. A similar type of lighting should be installed at the hump for the benefit of the car riders. The departure yard, as stated above, requires very little illumination other than that necessary for police protection. The inspectors are required to work under cars and between long lines of cars on adjacent tracks

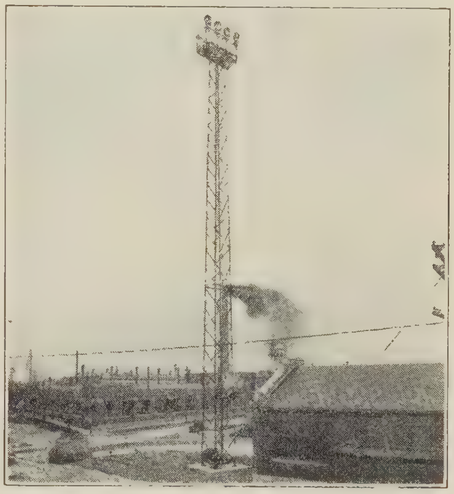

FIG. 1—A 110-FT. FLOODLIGHTING TOWER
In the Markham Yards of the Illinois Central Railroad

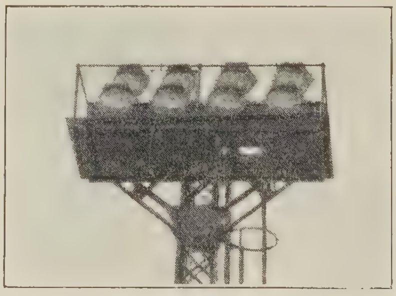

FIG. 2—PLATFORM WITH EIGHT 1000-WATT PROJECTORS
At Cedar Hill Yard of New York, New Haven & Hartford Railroad Co.

and therefore they carry lanterns. Moreover, it would be impractical and expensive to attempt to provide illumination for their benefit, and it would be impossible to show any financial saving or reduction of personal injury hazard.

Good illumination requires an even distribution of light without glare. In order to obtain this condition, lamps must be so spaced and so placed that there is no interference with one's vision. As space is valuable

1. Asst. Elec. Eng., The New York, New Haven & Hartford Railroad Company.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

in a railroad yard, and as the expense of installing and maintaining such an installation is extremely heavy, we have been compelled to seek some other solution of the problem. The method commonly used is the

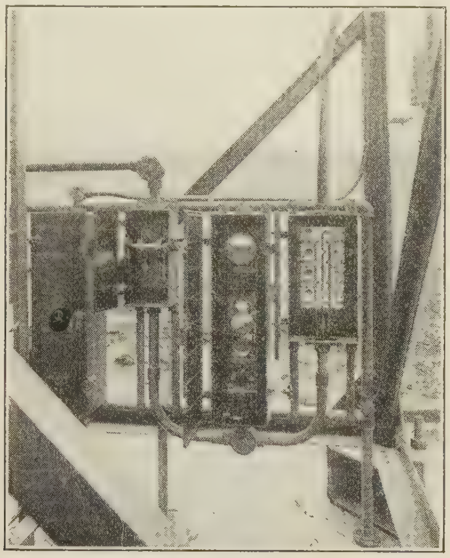

Fig. 3—Typical Switch, Meter and Cutout Installation at Base of Tower

Fig. 4—Projectors Mounted on Coal Pocket

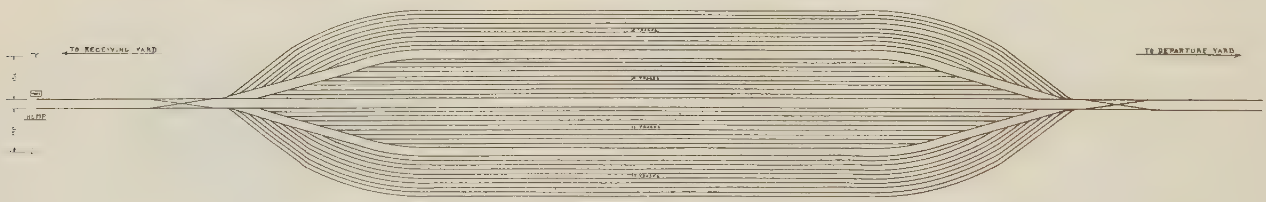

Fig. 5—Typical Lighting With Towers at Hump

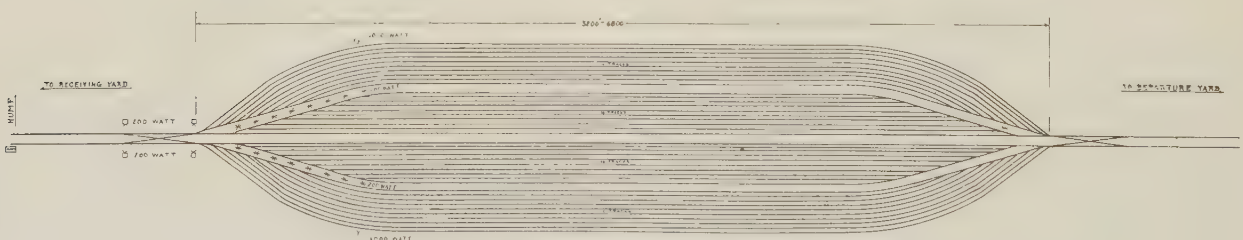

Fig. 6—Modified Lighting System Where Space at Sides of Hump is Scarce

installation of towers 75 ft. to 120 ft. above the base of the rail (Fig. 1), with a number of projectors equipped with 750-watt or 1000-watt lamps mounted on a platform at the top of the tower (see Fig. 2). The protective apparatus and switches are installed at the base of the tower (Fig. 3) in order to avoid all unnecessary maintenance labor. Practically the only necessity for climbing the towers is to change lamps and clean lenses and reflectors, which it is rarely necessary to do more often than every three months in winter and less frequently in summer. It is advisable to place control of the lighting in charge of the hump tower operator. This may be accomplished by installing a small start and stop button in a selected position, the manipulation of which energizes and de-energizes a contactor installed at the lighting tower. Another method is to install time switches at the base of towers which will automatically turn the lamps on and off at a predetermined time. The first method of control enables the tower operator to practise economy in current consumption during slack hours and yet furnishes sufficient light for police purposes. Tower lighting permits adjusting the position of the towers with the result that if space is not available for an ideal location, a change of 100 ft. or even 200 ft. does not materially decrease the efficiency of the installation. There is a possibility (although rarely available in classification yards) of taking advantage of high structures such as coal pockets and bridges for mounting projectors (see Fig. 4).

Classification yard lighting may be divided into three general classes or types, each requiring a different solution, as follows:

1. Yards employing hump riders and having hand-operated switches.

2. Yards employing hump riders and equipped with automatic switches.

3. Yards equipped with automatic switches and car retarders.

With the first type of yard, extreme care must be exercised to prevent interference with the switchman's vision on account of glare, as this is likely to be the cause of personal injury or accidents to the equipment. If space is available, two towers may be installed one on

each side of the hump and 300 ft. apart, as shown in Fig. 5. If lack of space at the hump makes this impractical, a so-called "modified distribution system"

FIG. 7—PROJECTORS ON POLE LINE IN SPEEDER-CAR SPACE
This is a view of the older installation at Cedar Hill which has been replaced by that shown in Fig. 11

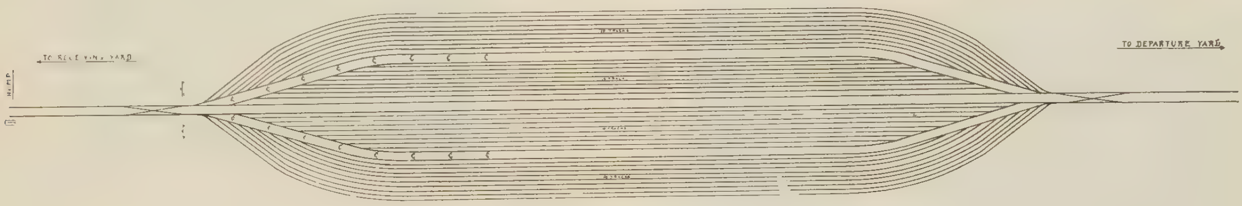

FIG. 8—TYPICAL LIGHTING OF NARROW YARD
500-Watt lamps on 35-ft. wooden poles 250 ft. apart

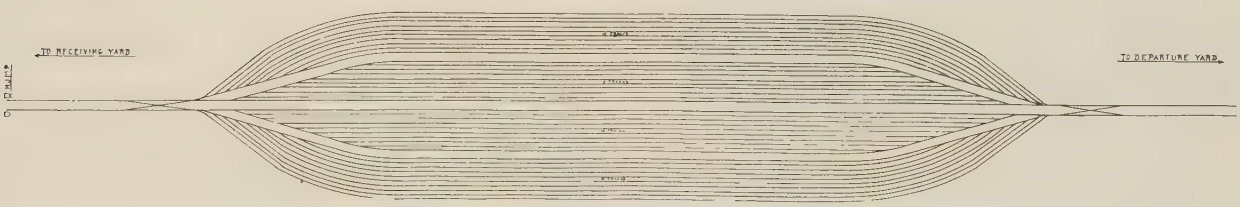

FIG. 9—TYPICAL LIGHTING OF A 3200-FT. YARD WITH TOWERS CLOSE TO HUMP

is advisable and the towers may be installed on the outer edges of the classification yard located. 300-watt angular reflectors mounted on poles in the space occupied by speeder tracks will provide illumination in the area between the hump and the point where the tower lighting becomes effective as illustrated by Fig. 6. In very narrow yards it may be found desirable to install 500-watt projectors with a 250-ft. spacing and an elevation of from 35 to 40 ft. above the tracks, the necessary pole line being installed in the speeder car space (Figs. 7 and 8). This latter method does not permit expansion and involves high maintenance costs as well as interference with the operators' vision by the poles; therefore it should not be installed. The cost of installing two towers at the hump amounts to approximately $7000, and involves a low maintenance cost, whereas the "modified distribution system" costs at least $8000 to install and results in a high maintenance cost.

With the second type of yard it is not necessary to consider the glare as there are no men in the yard and the current of traffic is in the direction of the light beam. One or two towers may be installed in the same relative position as in the first type of yard, or, if space is not available at that point, they may be installed close to the hump, as shown in Figs. 9 and 10. The cost of these towers will be approximately $7000. For a 3200-ft. yard no other lighting is required for the classification yard, an unobstructed view being obtained both from the hump and by the car riders (Fig. 11). The power required for a 40-track yard is approximately 16 kw. The installation and maintenance cost is low. The maximum illumination is at the switches, and the hump rider is enabled to detect track conditions clearly; moreover, in distant parts of the yard sufficient illumination is provided to permit the observation of low built cars in time to avoid collision with them.

Where yards are of extreme length it will be necessary to place at least two towers approximately 2000 to 3000 ft. from the hump, if possible (Fig. 12). Where space is not available for this, the towers may be installed on

FIG. 10—TWO 70-FT. TOWERS CLOSE TO THE HUMP
Each tower has eight 1000-watt projectors

the outer edges of the yard at the same distance from the hump. The wattage requirements for a 6000-ft. yard are from 12 kw. to 16 kw. and decrease pro-

portionately as the yard decreases in length. The increase in installation cost over a 3200-ft. yard will amount to approximately $12,000, making a total

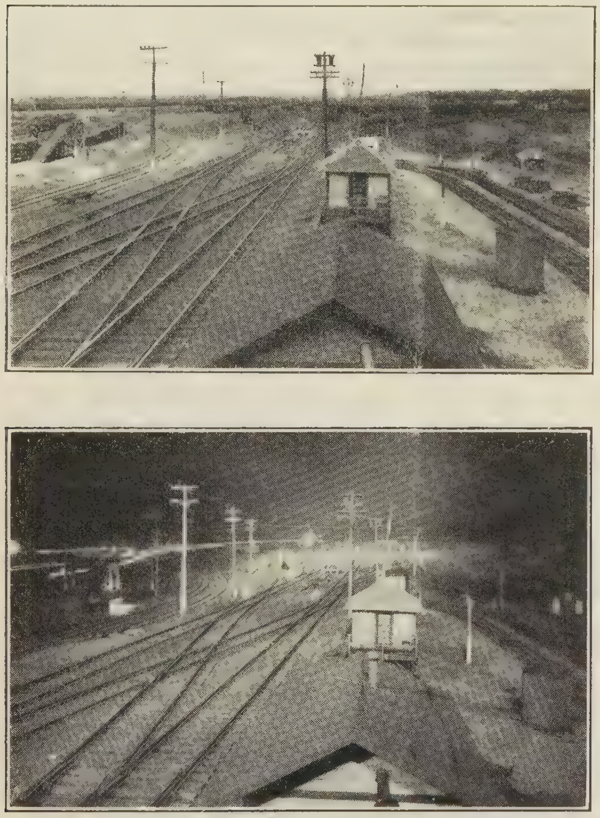

Fig. 11—Day and Night Views of Yard Lighted by Towers at the Hump

This is Cedar Hill yard of the New York, New Haven & Hartford Railroad. It is a 3200-ft. yard lighted by eight 1000-watt lamps on each of two 70-ft. towers. The pole holding two transformers and the pole beyond, holding two projectors, are part of the old system and will be removed.

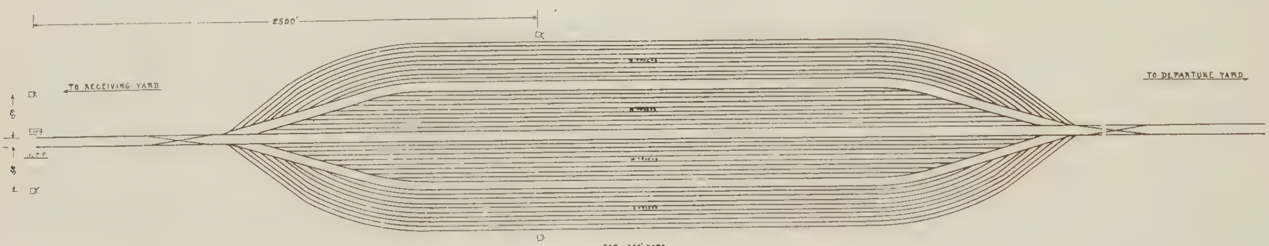

Fig. 12—Lighting Scheme For Very Long Yard

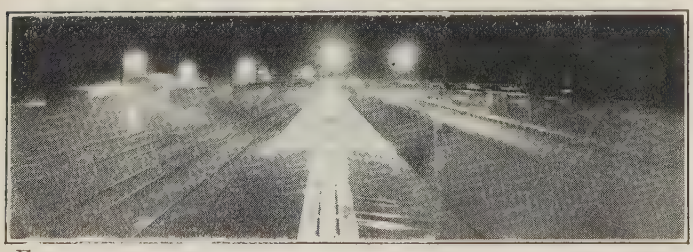

Fig. 13—Yard Illuminated by Floodlighting Projectors

This is the Selkirk yard of the New York Central Railroad.

installation cost of about $19,000, with a maintenance increase of slightly over 100 per cent. There is some possibility that at some time in the future, lamps of higher wattage may be used in the 5000- and 6000-ft. yards, with a resultant reduction in the number of towers required and a decrease in the installation and maintenance costs, but in considering any such proposition the possibility of interference with the vision of adjacent interests must be taken into account.

A distribution system similar to that shown in Fig. 8 would cost approximately $15,000, and would result in an increase of maintenance costs as compared with the tower lighting proposition of at least 1000 per cent.

Fig. 14—Yard View Showing Car Retarders

This large maintenance cost is due to the maintenance requirements of a large number of poles and projectors. Moreover, the poles would interfere with a clear view of the yard, and would be subject always to destruction on account of derailments with consequent delays in operation. The intensity of illumination is not so great with this type of lighting, although the distribution of light is more even. The only advantage over the tower lighting is in the case of yards so situated that there is a considerable amount of smoke and steam present. This may be considered as a special condition, as yards are usually located at a sufficient distance from engine houses and other smoke producing causes so that this advantage may be eliminated.

The third type of yard is similar to the first, but the personal injury hazard is eliminated as no hump riders or switchmen are required in the yard.

The retarder operators are located in secondary towers situated adjacent to the groups of retarders which they control. These towers are in the area of the ladder switches and are at an elevation above the tracks which permits an unobstructed view of the yard. Up to the present time no economical solution of this

problem has been worked out. If lighting as recommended for the second type of yard is installed, the glare interferes with the vision of the operators. In this connection it is possible that a visor effect may be obtained by painting the upper part of the tower windows, thereby shutting off from the operators' vision the direct beam of the lights.

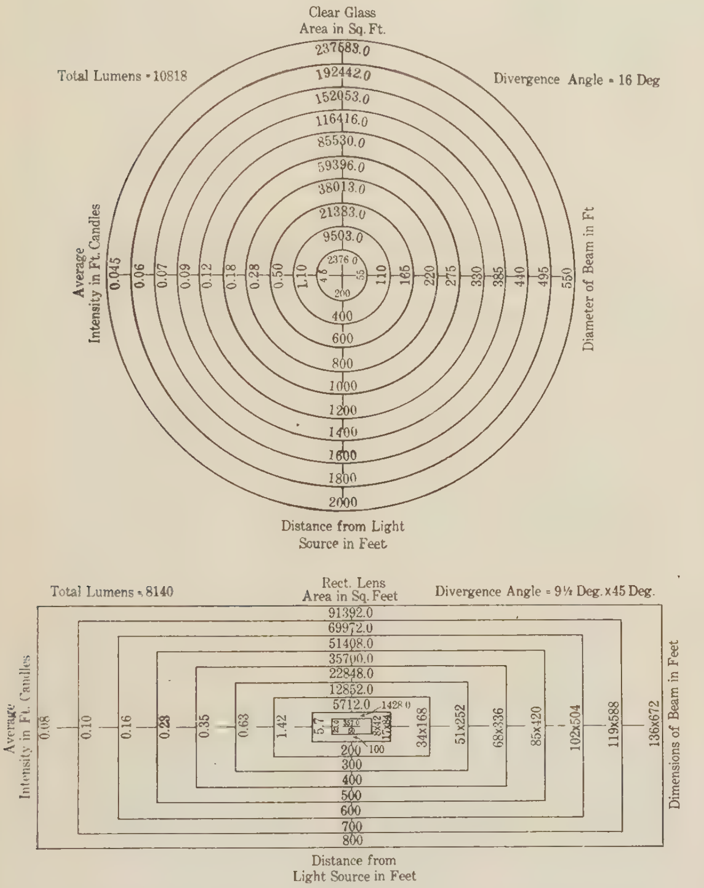

Fig. 15—Illumination From 1000-Watt Lamp in Floodlight Projector With and Without Rectangular Lens

A 1000-watt lamp with PS-52 bulb was used.

The position of retarders with respect to the operator is frequently such that it is difficult for the operator to observe the exact position of moving cars and of retarders at night on account of shadows (Fig. 14). A possible solution of this problem may be found in "marker lights" so placed that they will indicate when the braking effect on cars is to be applied to the retarders. This solution of the problem would be very economical.

Any system of local illumination covering retarder areas would be expensive and would cause interference with track clearances, which must be avoided.

With the increased experience of retarder operators there will be no necessity for illumination greater than that provided in yards using hump riders and automatic switches, since each operator will know the loading condition of his tracks and will be governed accordingly.

The same problem presents itself in lift-bridge operation, where actual practise has demonstrated that the experienced operator knows the position of his bridge at night and does not watch the indication lights, but prefers a marker light so placed that it will not be necessary for him to direct his attention in another direction.

The Committee on Illumination of the Association of Railway Electrical Engineers in November, 1923 reported the following advantages of yard lighting:

1. Speeding up of cars handled in the yard at night time.

2. Reduction in cars damaged by rough handling and collision in the classification yard with consequent reduction in claims, delay in delivery of goods, loss of service of damaged cars, etc.

3. Reduction in losses due to pilfering, on account of more effective policing possible with a well illuminated yard.

4. Improved working conditions and increased safety for employees working in the yard.

The studies and investigations of the Committee on Illumination in conjunction with the lamp and projector engineers, although not as yet completed or published, already have resulted in more efficient units and more

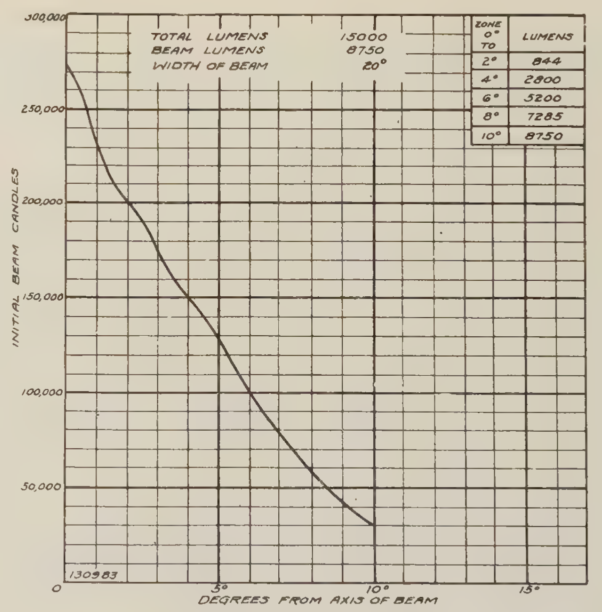

Fig. 16—Illumination Curve of Floodlight Projector With 1000-Watt Lamp

A 115-volt, 1000-watt, Mazda C lamp with PS-52 bulb was used

economical installations. The problem of lenses deteriorating with age, with resultant decrease of efficiency, has been practically solved. Curves and engineering data are now available (Figs. 15 and 16) which make it possible to plan installations with confidence that the results anticipated will be achieved. The problems of space lighting may be solved in various ways on account

of local conditions, but the fundamental principles are the same in all instances.

Floodlighting is not a "cure-all," but the results are satisfactory to the operating people and provide for them the operating conditions which they have been seeking.

No mention has been made in this discussion of silhouette effect, since it is considered that while theoretically this feature may have some value, at the present time the effect on the vision due to glare more than offsets the benefits. Further studies will be necessary before this type of installation can be recommended.

Recent Progress in Distribution Practise of the Brooklyn Edison Company, Inc.

BY J. F. FAIRMAN[1] Associate, A. I. E. E. and R. C. RIFENBURG[1] Associate, A. I. E. E.

Synopsis.—*Changes in the transmission and distribution system of the Brooklyn Edison Company during the past four years are briefly described and mention is made of the effect of these changes on the system's efficiency.*

In 1927 a low-voltage, a-c. network will be installed and this will be extended to care for the load growth until it becomes the principal supply system for low-tension energy in Brooklyn.

The plan of development is described in detail. The unique features are:

First, a suitably designed network unit consisting of a three-phase, 500-kv-a., low-loss transformer with an automatic network circuit breaker mounted in the low-tension pothead of the transformer.

Second, the operation of the high-tension feeders without regulators, at 27,000 volts, direct from the generating station.

Third, the ultimate plan of interlacing the high-tension feeders to reduce the overload on transformers and to maintain good voltage regulation with one feeder out of service, and to pick up overload in areas of different load characteristics to obtain the advantage of diversity. It is shown that this plan of development insures better service to the customer from every point of view, makes for safer working conditions on the system, results in general system improvement and involves less total investment as well as a considerable reduction in losses and operating costs.

The appendixes describe tests made to determine whether arcing and short-circuit faults in the network will be self-clearing, the permissible voltage fluctuations on incandescent lamps, and the dissipation of heat from transformer vaults.

* * * * *

THE changes in the transmission and distribution system of the Brooklyn Edison Company during the past four years, leading up to the proposed development of a low-voltage a-c. network, may be summarized as follows:

First, transmission voltages on the 60-cycle system have been increased from 6600 and 13,200 volts to 27,000 volts. This was made necessary by the difficulty of obtaining sufficient duct space in the streets in the vicinity of the new Hudson Avenue generating station to transmit the power away from the station at the lower voltages. Further consideration of the problem indicated that the higher voltage was also very much more economical.

Second, the primary distribution system from the substations has been changed from 2400 volts, two-phase to 2400/4150 volts, three-phase, which increased by 50 per cent the amount of power that could be transmitted over existing distribution feeders and at the same time reduced the losses by 25 per cent. In the substations themselves it was found that with the same buildings, by taking out certain unnecessary parts of the switching equipment, two-phase stations could be converted into three-phase stations of 50 per cent greater capacity with the addition of only a fraction of the equipment normally needed for this extra capacity.

Third, the overloaded d-c. system has been made comfortable and safe by changing over a sufficient amount of load to the a-c. system at points where this could be done most economically and with the least inconvenience to consumers. This plan of changeover was adopted in preference to reinforcing the inefficient d-c. system by adding feeders and mains and building additional d-c. substations at enormous cost. It was recognized frankly that with the art as then developed, short-time interruptions were more likely to occur on an a-c. system than on the d-c. system, but it was felt that careful attention to detail would give results materially as good, and that with the development of a closed low-tension network, an a-c. system would be substantially better than anything that can be developed with direct current.

An interesting result of these changes has been the increase in the overall system efficiency from a fairly steady value of 78 per cent during the preceding years to 82 per cent at the present time, when all of these changes have been practically completed. This increase in efficiency is illustrated in Fig. 1. The ordinates are computed each month by taking the ratio between the kilowatt hours sold and the kilowatt hours generated. This will continue to increase as a greater proportion of the total load is taken on the a-c. system, especially as the network system is extended.

The problem of an a-c. low-voltage network has been studied for the past three years and the first part of

1. Both of the Brooklyn Edison Company.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., Nov. 11-12, 1926.

this system will be in operation early in the summer of 1927. The network will be extended to take all the increase in load during successive years and will gradually supplant both the present radial a-c. system and the d-c. system.

The network will be entirely underground and will consist of single-conductor mains, solidly connected without fuses at all street intersections. These mains will generally be placed on one side of the street and will consist of three 500,000-cir. mil cables and one 250,000-cir. mil, bare copper neutral conductor. In the case of new construction or extensive revamping of old construction in densely loaded areas, the mains may be run on both sides of the street and the copper section will be 350,000 cir. mils.

Faults developing on these mains will burn clear. Experience on d-c. networks, extensive tests conducted by associates of the authors and similar tests conducted by others have definitely proven that failures on a system having 120 volts to ground will always burn

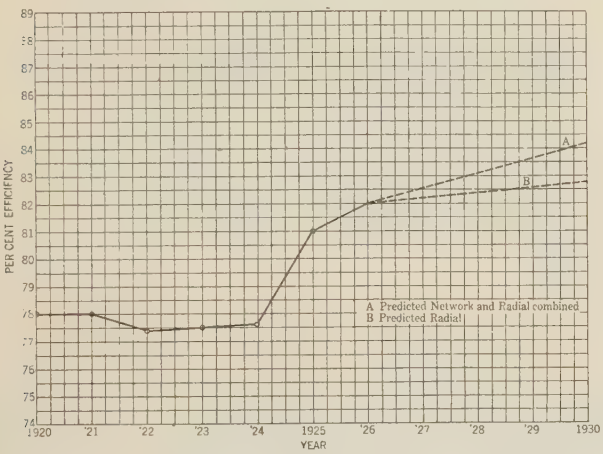

FIG. 1

clear with the size of cable and the capacity of transformers that will be used. These tests are described briefly in Appendix A.

The network will be three-phase, four-wire with 120 volts between phase wires and neutral and 208 volts between phase wires. These voltages were selected because the company's present standard voltage for lighting is 120 volts.

The matter of motor performance on voltages less than 220 volts has been discussed very extensively and the objections which were raised at first have largely disappeared for the following reasons:

First, all manufacturers guarantee their motors to operate satisfactorily at 10 per cent over or under the rated voltage.

Second, the large majority of motors are not designed within 10 per cent or sometimes even 20 per cent of their nameplate rating.

Third, on a network system the voltage regulation is much better, inherently, than on any other system, and consequently the voltage delivered to the motor terminals will be more nearly constant at the nominal value.

Fourth, in the majority of applications motors are normally under-loaded, in which case the efficiency and power factor are both better at the lower voltage and any reduction in speed is practically negligible.

Fifth, so far as starting torque is concerned, any desired value may be had, since all the common sizes of motors may be started by throwing them directly on to the line without producing an excessive voltage disturbance on such a network system. Indeed, in special cases it would be permissible to use an inverted compensator to apply greater than rated voltage to the motor terminals for starting.

Perhaps the strongest proof that these objections have been removed is that two of the leading manufacturers have recently instructed their salesmen in the Brooklyn district to quote standard 220-volt motors for use on this 208-volt system and to base performance data on 220 volts when it is requested.

Due to its better inherent regulation, the network system will eliminate the necessity for the rather complex service rules in common use. The principal reason for the adoption of rules restricting motor starting currents and the size of single-phase, low-voltage devices is to prevent excessive voltage fluctuations on combined light and power circuits. In order to determine the proper basis for such rules, in connection with the network system, the tests described in Appendix B were made and the results checked very closely with those obtained by other investigators. From these data, and the constants of the proposed system, it has been calculated that three-phase motors up to 50 h. p. and single-phase loads up to 10 kv-a., at 120 volts may be connected directly to the line at any point on the network without causing excessive voltage fluctuations.

It follows then that service rules can be simplified and reduced to a minimum and this will result in a greater commercial flexibility and improved relations with the consumers.

An objection to the three-phase, four-wire system has been raised in the matter of metering three-wire lighting services. Small three-wire services will be changed to two-wire services whenever the wiring on the customer's premises will permit, and large three-wire services will be changed to four-wire services by splitting up the three-wire circuits on the three sides of the *Y*. Such few three-wire services as necessarily remain can be metered by means of a standard two-element meter. No new services will be made three-wire.

Power will be supplied to the network from transformers located in vaults near street intersections. The transformers will be three-phase, 500-kv-a. and will have a full load loss less than 5 kw. These transformers have been specially designed for this low loss in order that the heat generated by the losses can be dissipated by conduction into the soil and by natural

ventilation without exceeding an ambient of 40 deg. cent. in the vault. Experience has indicated that the losses of two 100-kv-a. standard distribution transformers were about all that could be taken care of in the present vault. It was impracticable to increase materially the size of the present vault and it was considered undesirable to use forced ventilation or water cooling. Extensive tests were made to determine accurately the amount of heat which could be dissipated from the standard vaults. These tests are described in Appendix C. The results lead to the conclusion that losses up to 5 kw. could be handled by the present standard vaults.

The connections to the transformer will be made in two potheads, one on either end of the transformer, which will be sealed from the main tank by oil-tight insulating bushings, through which the leads pass. This is for the purpose of making connection in the field without the necessity of opening the transformers. The transformers will be equipped with filter-press connections and oil gages and will be filled with oil and sealed at the factory.

The twelve 500,000-cir. mil cables, forming the network mains which proceed in four directions, will be brought out from the bottom and will be connected to three busses inside the pothead. The neutral lead will also be brought out through and solidly grounded to the bottom of the low-tension pothead.

The low-tension pothead will also contain an automatic network circuit breaker which will connect the low-tension transformer leads at the top of the pothead to the three busses at the bottom. The breaker and its auxiliaries will be mounted on a panel which can be readily removed from the pothead. This is for the purpose of permitting quick and easy replacement of a faulty unit and for making repairs and major adjustments in the shop. The circuit breaker will trip out on reversal of power of the order of magnitude of the magnetizing power of the transformer and over a wide range of power factor from the lagging current of the transformer alone to the leading charging current of the cable. It will automatically reclose when the voltage at the low-tension side of the transformer is such as to feed power into the network. The relays are designed to prevent "pumping" of the breakers due to conditions which arise when one breaker fails to open. Heavy fuses on the network side of the breaker form a secondary line of defense to open the circuit in case of a failure in switch operation.

The breaker and the transformer will be furnished as a unit by the manufacturer. The transformer, with potheads attached, will be approximately 10 ft. long, 3½ ft. wide and 7½ ft. high. A special truck is being designed to transport the transformer and to lower it into the vault or to raise it out of the vault in case of necessary replacement. The roof of the vault consists of two removable center sections and two fixed end sections. The center sections of the roof are reinforced concrete slabs. These may be lifted out after the asphalt paving surface has been removed. In each of the fixed end sections there is a 35-in. round manhole. These manholes will be covered with heavy gratings instead of cast iron covers, which will permit a considerable circulation of air. A cross-section sketch showing the transformer in position in the vault is shown in Fig. 2.

The high-tension pothead of the transformer is to be filled with oil and will contain a grounding and short-circuiting switch. Provision will be made for attaching two conductors to each of the high-tension transformer leads in the potheads and for bringing out two three-conductor or six single-conductor cables through the bottom of the pothead. Thus a number of transformers will be connected to a feeder by looping the feeder into and out of the potheads of successive transformers, thereby eliminating *T* joints on the high-tension cable.

The high-tension cable will have a 350,000-cir. mil copper section and will be either single-conductor or

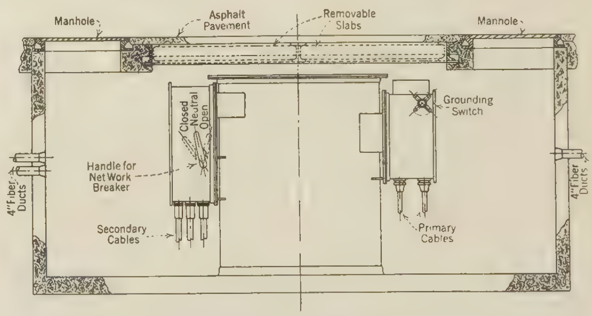

Fig. 2—Network Transformer in Vault

three-conductor with the individual insulated conductors covered with a thin metallic ribbon. In either case, the only high potential test required will be a conductor to ground test. It will not be necessary to disconnect the transformers from the cable while applying this test since the high-tension windings will be delta-connected and will be specially insulated for the high potential test. Faults will be located by means of a tracer current method. When it is necessary for work to be done on a feeder or transformer, adequate protection to the workmen is assured by grounding at a transformer on either side of the point at which work is being done, as well as at the station end of the feeder. Further protection from the possibility of back feed from the network may be obtained by manually locking out the low-tension circuit breaker.

Each cable joint will be equipped with a weighted expansion reservoir and the joint and the reservoir will be filled with oil. Extensive experiments have shown this to be a most satisfactory method of preventing failures due to voids which may develop either in the cable or in the joint subsequent to installation. A typical installation is shown in Fig. 3.

On a radial system of distribution it is necessary to do a great deal of work on live cables in order to reduce

the number and duration of outages. This, in the past, has limited the primary distribution voltage to around 2400 volts to ground, but even so it cannot be said that a safe working condition is obtained. On a properly designed network system, a primary feeder and its connected transformers may be taken out of service for an indefinite period without interrupting the service of any consumer. Consequently, since all work can be done on feeders or transformers while out of service, there is no limit to the permissible operating voltage from this viewpoint. Economic considerations then make it desirable to feed into such a network system directly from the generating station.

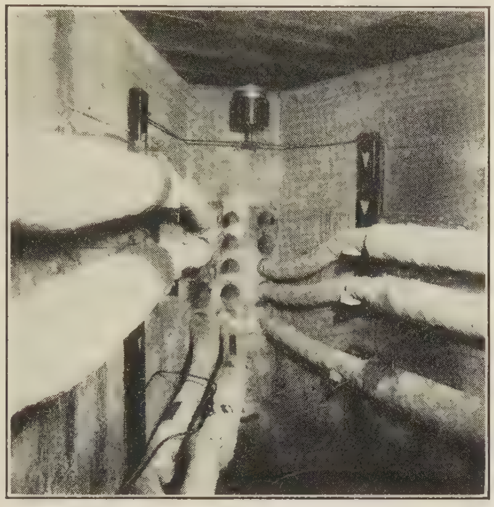

FIG. 3—SYLPHON RESERVOIR INSTALLATION ON 27-KV. CABLE JOINT

The high-tension feeders will be supplied from the 27,000-volt bus of the generating station. No feeder regulators will be used. Studies have shown that such a network without regulated feeders will have better voltage regulation than can be obtained on a radial system with regulated feeders. The bus voltage at the generating station will be varied in two steps during the day as is being done at the present time to reduce the range required on the feeder regulators in existing substations. Under normal conditions the voltage on the network will be within the present range on the radial system of plus or minus 3 per cent from 120 volts. In the emergency condition of one feeder out of service, the lowest voltage on the network will be around 110 volts to neutral with the corresponding value of 192 volts between phase wires. These values are based on full load at the time of the annual system peak so that ordinarily, with one feeder out, the voltage conditions will be considerably better. These figures are also based on the initial layout of transformers and will be improved as the transformer spacing decreases with a greater load density.

The continuity of service to the consumer on the network system will be greater than that which can be assured on a radial system since a complete interruption to an individual consumer can be caused only by burning off his service or by burning off the network mains in two places, one on either side of his service tap. On the present radial system, interruptions due to secondary troubles constitute only seven per cent of the total interruptions and these would be materially reduced on a network system. Careful attention to detail has made possible the development of a very reliable radial a-c. system. However, there is always a possibility of trouble with transformers, primary fuses and cut-outs, sectionalizing and tie switches, and cable, which will cause a total interruption to one or more consumers until the trouble can be isolated or repaired. The high-tension side of a network system is inherently simpler and hence less subject to trouble, and if a failure does occur, it will not result in an interruption of service to the consumer. If a complete shutdown of the generating station occurs, the network will automatically pick up its load as soon as the power supply is restored.

This system will be started in an area, a section of which is shown in Fig. 4. This area happens to have a very simple rectangular street layout and permits a correspondingly ideal layout of secondary mains, transformers, and high-tension feeders. The area will be supplied originally by three feeders and the transformers will be located as indicated in the figure. As the load density increases, additional transformers will be located midway between the first transformers, and three additional feeders will be brought into the area. With further load increases, the same plan will be followed so that ultimately there might be four feeders down each avenue with the successive transformers on different feeders. Under these conditions the outage of one feeder will place an additional load of approximately 25 per cent on the immediately adjacent transformers. Hence the loss of one feeder will not be a serious matter and ample time may be allowed for working on it, or the connected transformers, before putting it back into service.

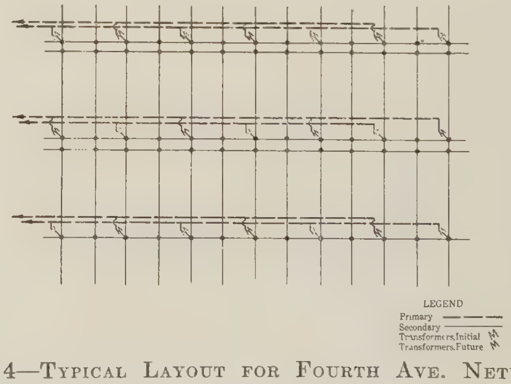

FIG. 4—TYPICAL LAYOUT FOR FOURTH AVE. NETWORK

As the network is extended to cover all of the underground area of the city, the feeders coming through a particular area will have come by different routes and

through areas having different kinds of load and will go on by divergent routes to areas of still other load characteristics. In other words, a group of feeders will not pick up their entire load in one area but will pick up load whenever possible in three areas of different characteristics, such as industrial load, office building and department store load, and residential load. By this extensive interlacing of the high-tension feeders, the advantages of diversity between areas of different load characteristics and of the reduction of extra feeder capacity required to carry the load during the outage of a feeder will be realized. The feeders will have a nominal capacity of 15,000 kv-a. each and as many as 40 transformers may be connected to each feeder in the ultimate development of the network.

Preparations are being made for the ultimate development by installing secondary mains of the proper size in all additions to the present radial underground distribution system and by building the new transformer vault wherever additional vaults are necessary. Whenever it is necessary to open the street for extensions or additional duct space, the duct layout for the ultimate network development in that area is installed. This work is justified in the present underground area on account of the relatively short time until the network system will cover the entire area.

In the case of vaults installed on customers' premises and served from the present radial system, the transformers are connected to give 120/208-volt, three-phase, four-wire service. When the network is introduced into the area in which such large customers are located, it will serve as the emergency supply to these customers by being tied in with the secondaries of the existing transformer installations and a network circuit breaker will be connected between the service and these transformers. Thus, part of the present substation capacity will be used as the normal supply to such large customers, part will be used to feed transformers in the street tied in with the network, part will be used to supply high tension customers, and the remainder will take care of the fringes outside of the underground development where the load density is light and where there is no justification for extending the network.

The reasons for adopting this plan of development are as follows:

First, and most important, is the fact that this system insures even better service to the consumer. Better service means improved continuity of service, improved voltage regulation, a shorter interval of time between the application for service and the actual connection, and minimizing the number of rules and restrictions imposed upon the consumer.

Second, and hardly less important, is the matter of greater safety to workmen on the system. The high-tension cables and transformers will be worked on only when they are out of service and adequately grounded.

Third, since the network system is essentially an underground system wherever the load densities are great enough to justify its development, it becomes possible to improve the appearance of the system by the removal of overhead lines.

Fourth, the savings in investment and operating costs and the increased system efficiency obtained by eliminating the necessity for substations economically justify this development. By 1935, when this system will have been well established, the total investment required will be approximately 10 per cent less than would be required for the present plan of radial development with substations, and the saving in maintenance, operation and losses on the distribution system will be around 35 per cent.

Appendix A

Arcing and Short-Circuit Tests on Lead-Covered Cable

The objects of these tests were:

1. To determine whether faults on a 120/208 volt system of the order of magnitude calculated for the proposed alternating-current network will clear themselves.

2. a. To determine whether faults on a 2400/4150-volt system are equivalent in current values in all cases and for practical purposes, to a dead short circuit.

b. To determine whether there is a critical value of current at this voltage above which arcs once established will persist and below which arcs will clear themselves.

Throughout the scope of these tests the physical and magnetic conditions encountered in service were reproduced as closely as possible. Three cables were placed in a 4 in. fiber duct, 16 ft. long, buried 10 in. below the ground, the ends of the duct being plugged with waste to prevent free circulation of air. Voltage was applied to all three cables, the fault being made on one cable only. This was for the purpose of determining whether the fault would injure the remaining cables sufficiently to cause them to fail as well as to keep physical conditions as nearly as possible to those encountered in service.

Power was supplied through a 10,000-kv-a. feeder and transformer direct from the main generating station. Oscillograph records of current and voltage were made for all tests.

Tests on Cables at 120/208 Volts. Tests were made on standard 350,000-cir. mil, 300-volt, 6/64-in. rubber, 1/8-in. lead cable. The fault was placed in the center of the cable by embedding a No. 8 brass screw in the copper and soldering the head to the lead sheath. One leg of a 100-kv-a. transformer was connected to the two ends of the loop and the other leg to the lead sheath. This test was repeated first with three and then with six transformers in parallel; the resultant currents into the fault being 7500 amperes, 13,000 amperes and 19,000 amperes, respectively. In all three tests the fault cleared itself by melting the brass screw without establishing an arc. Similar tests were repeated in an

effort to make a lower resistance fault by various methods until a solid lead knob was wiped between the bare conductor and the sheath. The results in all cases were the same; *i. e.*, the fault cleared itself by melting away the lead without establishing an arc.

Copper-to-copper short circuit tests were also made to determine whether faults of this nature would clear themselves. A copper-to-copper short circuit was made through a 32-ft. loop with a joint in the center of the loop. Tests were made for the maximum (17,000-ampere) and minimum (3000-ampere) current values calculated for the network. In all cases the paraffin in the joint melted but the conductor burned apart, clearing the fault before the joint failed.

Tests on Cables at 2400/4150 Volts. These tests were made on 4/0-, 11/64-in. rubber, 1/8-in. lead, 5000-volt cable. Three cables were placed in one duct and a fault placed on one cable as in the low-voltage tests, all three cables being energized. It was found during the first tests that very soon after the arc was formed the fault spread to all three phases. Since reactors to limit the current in all three phases were not available, subsequent tests were made with only one phase energized.

Tests were made over a range of from 360 amperes to 1750 amperes with the results that in every case the arc continued to burn until it reached the end of the ducts, making it necessary to clear the fault by opening the breaker.

As the result of these tests the following conclusions have been reached:

1. All 120/208-volt faults will clear themselves without damage to other cables in case of ground faults.

2. 2400/150-volt faults, once an arc is established, will continue until the voltage is interrupted at its source.

3. All other cables in a duct on a 2400/4150-volt system where an arcing fault exists will break down, causing a phase-to-phase short circuit.

Results of similar tests which confirm the above are described in *Self-Protecting A-C. Networks* by A. H. Kehoe, TRANS. A. I. E. E., Vol. XLIII, p. 850.

Appendix B

PERMISSIBLE VOLTAGE FLUCTUATIONS ON LIGHTING CIRCUITS

The principal reason for the adoption of rules restricting motor starting currents and the size of single-phase, low-voltage devices is to prevent excessive fluctuations in voltage on combined light and power circuits and consequent annoyance to lighting customers. In order to determine a proper basis for such rules in connection with the network system, a number of tests were made to obtain answers to the following questions:

1. What change in voltage occurring instantaneously will produce a noticeable change in illumination of standard lamps?
2. What is the relation between the magnitude and frequency of a periodic voltage change that will produce a noticeable change in illumination?
3. What rate of change will be noticeable?
4. What changes will be objectionable?
5. How are the above affected by different types, ratings and arrangements of lamps?

The conditions under which the tests were made were as follows:

A room was equipped with six suspended outlets so arranged as to allow varying the distance from the lamp to the working plane. Each socket was equipped with an opaque cone shade. The observers were screened from one another and each one indicated independently when he observed a fluctuation and when in his judgment the fluctuation became objectionable. A motor-generator set was used to supply a steady voltage for the lamp circuit. In series with one lead a variable slide wire resistance was inserted, so arranged that it could be switched in and out of the circuit by means of a snap switch or a motor driven commutator. A low reading voltmeter was placed in parallel with this resistor so that the actual voltage drop could be measured.

The first test consisted of switching in and out the resistor at 5-sec. intervals and gradually increasing the drop until all observers reported that they had noticed the fluctuation, then continuing to increase the drop until they had all reported that the fluctuation was objectionable. Twenty-five and 50-watt Mazda B lamps and 75- and 100-watt Mazda C lamps were used. Successive tests were made with the lamps at 18 in. and 72 in. above the observer's reading plane.

The lowest fluctuation observed was a one-volt drop with the 25-watt lamp 72 in. above the reading plane, which gave the lowest illumination intensity. In general, very few of the observers could detect a change smaller than 1½ volts under any of the conditions imposed and some observers had difficulty in detecting a fluctuation smaller than 2¼ volts. It was found that the higher the illumination intensity the greater was the fluctuation in voltage necessary to produce a noticeable change in illumination. The averages of the results for all observers varied from 1.33 volts for the 25-watt lamp at 72 in. to 1.66 volts for the 100-watt lamp at 18 in., which gives an average for all observers under all conditions of 1½ volts.

All observers agreed that the fluctuations become decidedly objectionable when the voltage was varied from four to five volts. As mentioned before, the interval between changes was five sec. and undoubtedly a longer interval would lead to different conclusions as to what fluctuation was objectionable.

The second test consisted of increasing and decreasing the voltage gradually by moving the slide on a resistor by hand at as nearly uniform a rate as possible. It

was found that the change could be noticed when the rate of change exceeded 2½ volts per sec. This was checked several times with very uniform results. One lamp only was used in this experiment and one distance from the working plane. The results of the first experiment led us to believe that no great difference would be found by using different sizes of lamps at different distances.

The third test consisted of cutting the resistor in and out by means of a motor-driven commutator, setting the resistor for a certain drop and increasing the speed of the commutator until the flicker disappeared;

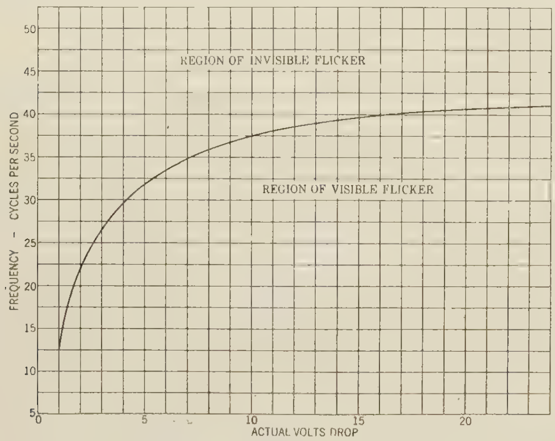

Fig. 5

then decreasing the speed until it reappeared and averaging the results. It was found that no flicker at any frequency could be observed for drops smaller than one volt; also the flicker entirely disappeared for all voltage drops at frequencies above 45 cycles per sec. The results of this test are shown on the curve in Fig. 5.

Before making the above tests, a search was made of the literature and inquiries were made of various individuals and organizations from which sources it was hoped to obtain information on this subject. It seems that a great deal of information is available on the relations between the magnitude and frequency of periodic voltage fluctuations which produce visible flickering of incandescent lamps, but that relatively little work has been done on the problem of determining when non-periodic and infrequent voltage changes become objectionable. The earliest study of this problem which was found was made by Mr. William Kunerth, of Iowa State College, and was published in the August 1915 number of the *Lighting Journal.* C. A. Williams, of the Philadelphia Electric Company, in January 1924 presented a paper on "Voltage Fluctuations and Its Effect Upon Lighting" before the Pennsylvania Electric Association. In the June 1924 number of the A. I. E. E. Journal there appeared an article by A. H. Kehoe, of the United Electric Light & Power Company, on "Underground A-C. Networks." Under Appendix A of this article he describes some tests on the effect of voltage variations on incandescent lamps.

The information obtained from the tests and from the other sources mentioned seems to indicate:

1. That a sudden change of voltage of less than two volts does not produce a noticeable change in illumination, unless it is periodic.
2. That a sudden change of voltage of more than six volts will probably be objectionable if it occurs more frequently than once or twice an hour.
3. That any noticeable periodic fluctuation or flicker is objectionable.

In connection with the above, two things should be borne in mind:

First, that the values were obtained when the observers were expecting to notice changes; hence they are lower than would have been noticed under ordinary conditions. Second, that all investigators are in much closer agreement as to what changes are noticeable than as to what changes are objectionable. So many factors, psychological and physiological as well as electrical, are involved in the problem of objectionable voltage variations that a more extended study would seem to be warranted. In his article, Mr. Williams emphasizes that we have made only a step toward standardizing the limits of voltage fluctuation for satisfactory service to lighting customers.

Appendix C

Heat Dissipation From Transformer Vaults

The transformer vaults in use in the streets of Brooklyn were designed to accommodate two 100-kv-a.

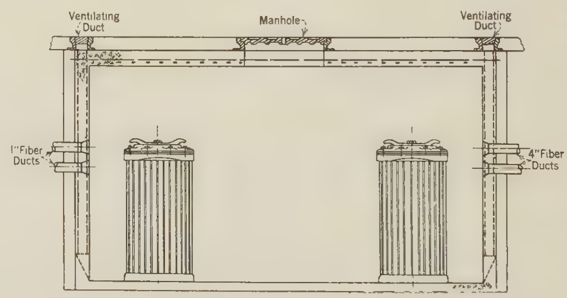

Fig. 6—Standard 200-Kv. Transformer Vault

transformers. These vaults are 4½ ft. wide, 14 ft. long, and 8 ft. deep. Access is obtained through a 35-in. manhole located in the center of the roof. The vaults are ventilated by natural circulation of air through banks of three 4-in. fiber ducts at either end and through the openings in the manhole cover. Experience has indicated that this ventilation together with the absorption of heat into the surrounding soil will take care of the losses of two 100-kv-a. transformers under ordinary load conditions the year round without exceeding an ambient temperature of 40 deg. cent. in the vault. Such a vault is shown in section in Fig. 6.

Before deciding upon the type and size of transformers to be used for the network, it was desirable to determine accurately how much heat could be conducted through the walls of the vault into the surrounding

soil and how much could be carried away by the circulation of air through the vault using various types of ducts and manhole covers or gratings.

Tests to determine the conduction of heat through the walls of the vault were made in a standard vault with the ventilating ducts closed. Bayonet heaters were placed in two 100-kv-a. transformer tanks filled with oil. These heaters were arranged to give the equivalent losses of different sizes of transformers under various load conditions. Thermocouples were imbedded in the walls of the vault and at distances up to eight feet away from the vault in the earth at various depths. They were used also to measure the temperatures of the oil and air in the vault. Starting with the vault and transformers cold, a constant amount of power was supplied and the temperatures taken at regular intervals until all temperatures became constant. The vents were then opened and temperature readings taken until they again became constant. This was repeated several times with different amounts of power, both for constant loads and for various load cycles. These tests occupied a five-month period, from February to June, so that some data were obtained on the seasonal effect on soil temperatures. From the data obtained during these tests Formulas **1** and **2** were derived.

Further tests to determine the effect of various types and arrangements of ventilating ducts and cover gratings were made using a box built to the dimensions of the vault. The same heating arrangement was used, and air temperatures at various points were measured by means of thermocouples. Air velocities in the inlet ducts were measured as a check on other data. Various constant amounts of power were supplied and readings taken when temperatures became steady. The process was repeated for different sizes of inlet and outlet ducts, both with and without cover gratings. The data thus obtained were used to check Formula **2**.

The constants in the following formulas apply to the size of vault and the ventilating arrangement finally decided upon, which is shown in Fig. 2. A removable canvas tube extending down from one manhole to a point 18 in. above the floor of the vault will lead air into the vault, whence it will flow around the transformer and out of the other manhole.

Formula **1**. For dissipation of heat by conduction through the walls of the vault:

$$W_1 = 95.8\,(T_1 - T_2) + 0.6325\,\epsilon^{0.1(T_1 - T_2)}$$

where

W_1 = watts dissipated through vault walls,

T_1 = average air temperature in vault,

T_2 = soil temperature.

Formula **2**. For dissipation of heat by natural ventilation:

$$W_2 = 30.74\,A^{0.5}\,(T_1 - T_3)^{1.6}$$

where

W_2 = watts dissipated by ventilation,

A = gross ventilator duct area in square feet, where net area is 65 per cent of the gross area,

T_1 = average air temperature in vault,

T_3 = outside air temperature.

PUBLIC LIGHTING AND MOTOR HEADLAMPS

The present position in regard to powerful motor headlights is decidedly unsatisfactory. These powerful beams, projected in a restricted radius on pedestrians and other road users, are a source of profound irritation and something will have to be done to regularize or provide an alternative to their use. What is the remedy? Mr. Edward Fryer, of the Automobile Association, states that in New York the use of powerful headlights is forbidden in all streets. A prohibition of that kind, however, can commend itself only as a satisfactory solution when the alternative means of lighting—public lamps—give the requisite degree of illumination to render street traffic safe. It is an undoubted fact that in many towns, particularly those with boulevards of trees, the shadows thrown upon the road surface are a real peril, compared with which powerful headlights are the lesser of two evils. We do not think, as one speaker suggested at the meeting of Public Lighting Engineers, that the Automobile Association is in the slightest way attempting to shelve some of its responsibilities in this matter. What that Association is out for is a maximum of comfort for its members, which maximum is only realizable coincident with a maximum degree of safety both to motorists and other road-users.

The lighting up of country roads with the object of rendering the use of powerful headlights unnecessary may be left for future determination. Public lighting of that kind is unlikely to mature save in a gradual way as such roads come within the compass of mains linking up lighting undertakings. But in the towns of the country generally public lighting systems already prevail. Are they adequate to warrant prohibition of the use of powerful headlights? The answer is decidedly in the negative, speaking generally. It must be the aim of public lighting engineers to reverse the answer, for mechanically propelled vehicles are to-day a necessary part of communal needs, used not merely for private pleasure, but in a much greater degree for the needs of business. Public lighting must keep pace with these modern needs, and not leave it to motorists to make up the deficiency by which it falls below the standard of reasonable safety. In that regard public lighting engineers will find much work lies to their hands, educative and otherwise.—*The Gas World* (London) October 9, 1926.

Automatic A-C. Network Switching Units

BY G. G. GRISSINGER[1]

Non-Member

Synopsis.—The desirable characteristics of automatic switching units designed for application in secondary a-c. distribution networks are discussed in this paper. Descriptions are given of units designed for wall mounting and for manhole installation. These units are connected to the low-voltage side of the network transformer for the purpose of automatically disconnecting a transformer from the low-voltage network whenever a fault develops on a primary feeder connected to the transformer. When proper voltage is restored to the primary feeder the unit should automatically reclose.

* * * * *

IN order that low-voltage a-c. distribution systems may compete satisfactorily with low-voltage d-c. distribution systems, it is necessary that they have characteristics which are as good as, if not better than, the characteristics of the d-c. systems. The cost of the a-c. system, likewise, must be no greater and preferably less than the cost of the d-c. system. It is well known that the present-day d-c. systems give excellent and reliable service and partly for this reason, as well as for the reason that for a good many years a competitive a-c. system had not been developed, they have become firmly entrenched in the older load centers of our large cities.

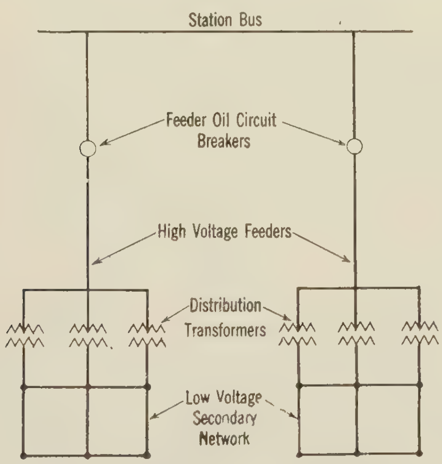

FIG. 1—SECTION OF A TYPICAL RADIAL-FEEDER DISTRIBUTION SYSTEM

That the d-c. systems give such reliable service is primarily due to the fact that they permit faulty sections to be cut out automatically without paralyzing service to any customer. As an additional safeguard, storage batteries are also used to a certain extent as standbys. In addition, the d-c. system provides good voltage regulation.

It is apparent, therefore, that an a-c. system, in order to satisfy present-day commercial demands, must have at least the characteristics mentioned above.

The simplest form used in low-voltage a-c. distribution (see Fig. 1) is the radial feeder system wherein each feeder independently serves a particular load area. Since this load area is entirely dependent upon its one supply feeder, however, a fault on that feeder completely paralyzes service until the fault is corrected and the feeder is reconnected. A condition of this kind cannot be permitted in an important industrial load area. Furthermore, the transformer and feeder capacity required is greater than would be necessary if the secondaries of the transformers on the several feeders could be connected in parallel as shown in Fig. 2, because each bank of transformers must be large enough to carry the maximum load in its section and no advantage can be taken of the diversity factor of the loads in adjacent sections. A minor factor also is that the all-day efficiency of any such system does not compare favorably with that of a d-c. system because of the losses in the distribution transformers and induction regulators at light loads or no load. As a result of these disadvantages, a great deal of attention has been paid to improvements in the radial scheme.

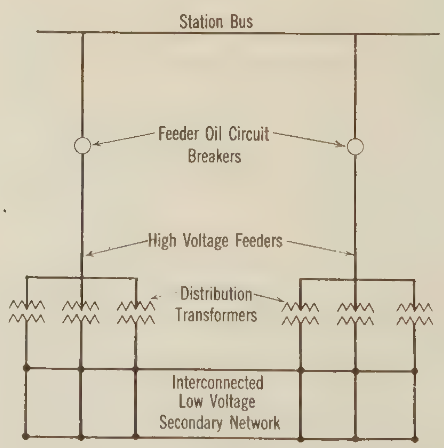

FIG. 2—SECTION OF AN INTERCONNECTED SECONDARY NETWORK DISTRIBUTION SYSTEM

Numerous methods have been proposed for improving the reliability of the radial system and some of these are still in use. For example, important loads are sometimes fed by duplicate feeders and if one feeder fails, the load is thrown onto the other feeder by means of either automatic or hand-operated switches. Duplicate equipment must be provided, which increases installation costs. Numerous other schemes, such as inter-

1. Supply Engineering Dept., Westinghouse Elec. & Mfg. Co.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., November 11-12, 1926.

laced primaries, emergency tie schemes, loop feeders and so on, have also been successfully used, but the most recent and to date the most satisfactory system worked out from the standpoint of cost, voltage regulation and reliability is the interlaced secondary network system. (See Fig. 2.)

In this system each high-voltage feeder, whether it be 2200, 4000, 13,200, or 27,000 volts, is connected through an overload automatic oil circuit breaker at the substation to a number of banks of distribution transformers, the number and size of these banks depending upon the nature and distribution of the load. It may be well to mention here that the minimum economical load density which will warrant the installation of a network system is approximately 75 kv-a. per average city block area. The secondaries or low-voltage sides of these transformers are connected to the secondaries

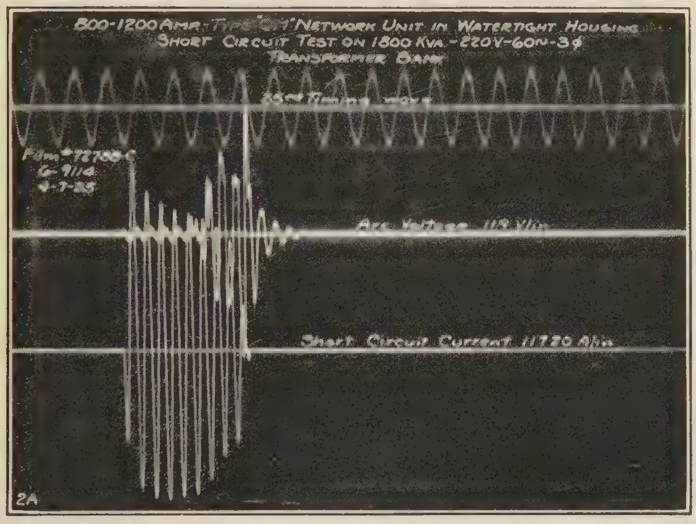

Fig. 3—Short-Circuit Test on 800/1200-Ampere Network Unit in Watertight Housing

In test made on an 1800-kv-a., 220-volt, 60-cycle, three-phase transformer bank, the maximum peak voltage recorded was 268 volts and the maximum peak current was 30,300 amperes

of the transformers on adjacent feeders to form an interconnected or interlaced secondary network. In this system, failure of one or even two feeders does not necessarily discontinue service to any particular area, since this area will continue to be fed from the other feeders through the interconnected network. It is evident, however, that some means must be provided for automatically disconnecting each distribution transformer on a faulty feeder from the network, even though the feeder is automatically disconnected at the substation by means of the feeder oil circuit breaker, since power will flow from the network into the feeder fault. The automatic network unit has been designed for this purpose.

The first requirement of a network unit is that it shall automatically and positively open in the case of a primary feeder fault. It is not so essential, and in fact it is not desired, to have it open on direct power flow which would obtain in the case of a network fault since it is common practise to hold onto the load and burn such faults clear. Of course, faults in a consumer's premises are cleared by local protective devices such as fuses or overload circuit breakers. Laboratory and field tests have shown that it is possible to burn all secondary short circuits clear provided the cable capacity is not too great and sufficient energy is available to maintain voltage. A high-resistance fault may hang on, but in this case the small amount of current flowing will not cause material damage. Service experience has so far confirmed these results.

The second requirement of a network unit is that it shall automatically reclose when proper voltage is restored to the feeder to which it is connected even though the entire network is dead. There has been some discussion concerning the necessity of this, but unless the network system is small, with comparatively few banks of transformers per feeder installed near each other, it is evident that considerable trouble will be experienced in reclosing each network unit by hand after a feeder has been repaired. It is possible, of course, to run pilot wires from each unit back to the substation so that reclosing the units could be controlled by push buttons, but pilot wires are none too desirable and in addition to adding to the complication of the underground system, would undoubtedly result in a more expensive system.

The majority of the secondary network systems so far installed are three-phase, four-wire, either 115/199 or 120/208 volts, 60 cycles. One installation employs three-phase, seven wires, where distribution transformers with tapped secondaries are used in order to obtain 115 volts to neutral for lighting loads and 220 volts across phase for power. There are also several two-phase, five-wire systems, one of which employs primary loop feeders. The general trend, however, is towards the use of three-phase, four-wire distribution.

With the exception of a single case, automatic reclosing low-voltage network units so far developed by the company with which the writer is connected have been designed for application to three-phase, 60-cycle systems. Each three-phase unit consists of a three-pole carbon circuit breaker operated by an automatic mechanism which in turn is controlled by three single-phase induction-type master relays. This equipment is mounted together on a panel. The carbon circuit breaker was chosen in preference to an oil circuit breaker chiefly from the standpoint of economy and compactness in design. It has been found entirely adequate for this type of service.

The circuit-breaker unit is front-connected so that it may be mounted against a wall for installation in dry vaults in buildings or in a watertight housing for manhole service. (See Figs. 4 and 5.) It is available in 250-, 500-, 800- and 1200-ampere capacities for 250 volts, 60 cycles, or lower voltages.

It has been stated previously that the majority of installations employ three-pole units. It would be possible in order to reduce the size of individual units, thus making each one easier to handle, to use three single-pole units. This would have the disadvantage, however, of greater cost due to the use of three separate housings (for manhole service) and three separate operating mechanisms. Further than that, maintenance would be greatly increased and lack of space in manholes might prohibit their use. It is true that in one certain two-phase installation two units are used, but this is due in great part to system conditions and requirements.

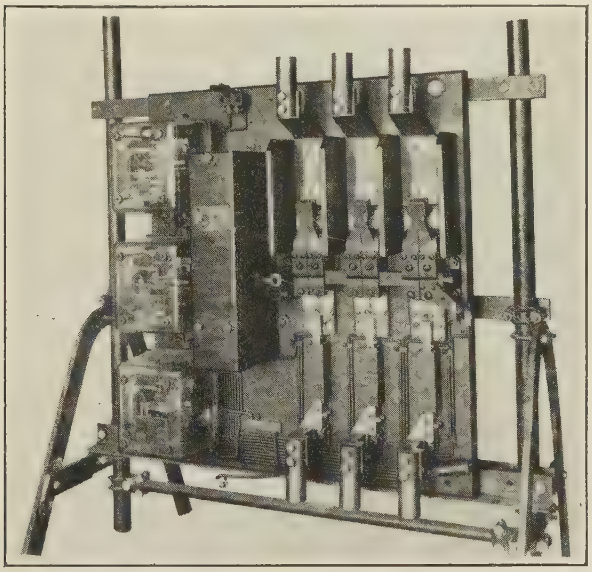

FIG. 4—NETWORK SWITCHING UNIT MOUNTED ON FRAME

This is a three-pole, 500-ampere, 60-cycle, 250-volt unit for three-phase, four-wire circuits

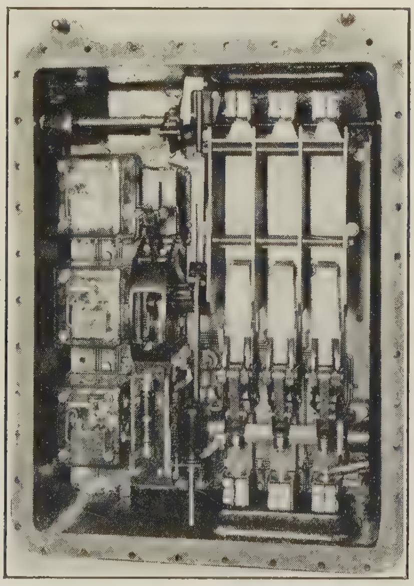

FIG. 5—NETWORK SWITCHING UNIT IN SUBMERSIBLE HOUSING

This is a three-pole, 1200-ampere, 60-cycle, 250-volt unit for three-phase, four-wire circuits

That these units must be compact in design is evidenced by the fact that all sizes up to and including the 1200-ampere capacity must, when mounted in their housings, go through a 35-in. diameter manhole opening.

When applied to manhole service where flood conditions are likely to be encountered, as stated above, the entire unit including relays is mounted inside a watertight housing. No breathers or pressure outlets have been provided in this housing, since it has been found by test that the pressure set up in the housing when the circuit breaker opens a short circuit is small. By making the housing completely tight, all moist air and gases are excluded and there is no danger of an arc from the circuit breaker causing a manhole explosion. The housings have been designed to withstand a maximum external pressure of 6½ lb. per sq. in. over and above atmospheric pressure. This corresponds to the mean pressure resulting from a flood water head of approximately 15 ft. which according to all data available on present manhole installations is the maximum to be expected. The housing proper is made of cast iron. The cover, however, is made of aluminum or sheet metal in order to allow easy handling. Suitable gaskets make the joints watertight.

Air pressure is applied internally to test the gaskets as well as the porosity of the metals which are impregnated with sealing compound.

Bronze bolts are used. Lead-covered cables from the distribution transformer are brought into the bottom of the housing through brass bushings clamped in a brass bushing plate. The brass bushing plate reduces the magnetic flux density in the immediate vicinity of the cables and thus reduces eddy-current losses and the corresponding heating. Lead-covered cables are taken out at the top of the housing for the connection to the network. The cable ends are covered with special micarta sleeves which prevent dripping of cable compound. The main cables and a ground lead connected to a lug at the bottom of the case are the only external connections.

The cables are made watertight where they enter the housing, by means of plumbers wiped joints between cable sheath and tinned bushings. An external removable operating handle is provided. A shaft turning in a stuffing box serves to operate the interior mechanism. There are three definite positions of this handle designated, open, neutral and closed.

With the handle in the open position, the mechanism relay coil of the circuit breaker is cut out of circuit. The circuit breaker, therefore, is tripped open and cannot reclose automatically, and thereby provides a safety feature for a man working on the circuits.

In the neutral position of this handle the circuit breaker is free to open or close electrically. This is the normal operating condition.

When the handle is in the closed position the circuit breaker is locked closed so that it cannot open electrically. This position will be used only in extreme emergency.

The mechanism of the network unit is energized or de-energized by means of the master relays. When the contacts of the relays are closed and the transformer is alive, the mechanism closes the network circuit breaker, and when the contacts of the relays are opened the circuit breaker opens. The contacts of all three relays are connected in series and hence it is necessary that all contacts be closed before the circuit breaker will close. On the other hand, it is necessary for only one relay to open its contacts in order to trip the circuit breaker.

The master relays are so designed that they will not close their contacts unless the transformer voltage is at least one-half volt higher than the network voltage and not more than 10 deg. out of phase with it. The relay contacts, however, are closed normally by a spring if the network is dead, and since the operating coils on the circuit-breaker mechanism are connected across the distribution transformer it is possible to start up a dead network by closing in the necessary feeders at the substation. The master relay contacts will open, however, as soon as energy flows from the network into the transformer. It is thus possible to disconnect any feeder from the network by opening the oil circuit breaker on that feeder at the substation, since the resulting reversal of energy equal to the magnetizing energy of the distribution transformers is sufficient to trip all of the network units on that feeder. The substation operator, therefore, may connect or disconnect feeders at will, allowing only those feeders to remain connected which are actually required to carry the load.

If the relay current coils were connected directly in the line or across a non-inductive shunt, they would have to be designed to carry an extremely wide range of current and at the same time be sensitive over that range. A novel and effective means of overcoming this is afforded by the so-called reactive shunts. Each shunt is composed of a bundle of laminated iron stacked on a copper bar. The current coils are connected directly across these shunts which are in series with the line. The current coils, therefore, receive only a portion of the line current and the percentage of line current which they receive decreases rapidly with increasing current owing to the saturation of the iron. This permits sufficient sensitivity to operate the relay and open the network unit on small amounts of reverse energy such as the reverse magnetizing energy of a distribution transformer. On the other hand, due to the fact that the iron saturates at a comparatively low value of current, the shunt reactance drop for a large line current does not reach an excessive value.

Fuses are provided, one in series with each pole of the circuit breaker, which serve as an ultimate protection if the circuit breaker at any time fails to open on a feeder short circuit. It is intended that secondary short circuits burn clear, but in the case of a secondary short circuit very close to a transformer, sufficient current may flow to blow the fuses of the network unit connected to that transformer.

The fuses are rated at about three times the rating of the circuit breaker. To prevent oxidation, the fuses, which are the open link type, are coated with a special varnish.

It has been stated that the operating coils of the circuit breaker mechanism are connected across the distribution transformer and not across the network side of the circuit breaker. This is quite necessary. If the network is dead and the distribution transformer is made alive by the closing of the feeder circuit breaker, the operating coils, being connected to the transformer side, close the network unit as soon as the master relays close. If they were connected to the network side they could not do so. Likewise, if the feeder is dead and the network is alive, faulty operation of the relay cannot close the network unit since the transformer would be dead and the operating coils therefore would not be energized.

The energy losses in the complete network unit are comparatively small; when the circuit breaker is open a slight amount of energy is used in the phasing coils and potential coils of the relays and when the circuit breaker is closed additional losses take place in the circuit breaker conducting parts and mechanism relay coil but all of these losses are small. The loss in the closing coil of the circuit breaker is negligible since this coil is in circuit only during the short time required to close the circuit breaker.

Mention has been made of a mechanism relay coil. This, in the majority of cases, is a low-voltage coil which acts as an intermediary between the master relays and the circuit-breaker closing coil. It also serves to trip the circuit breaker. A shunt-trip coil could be used in place of the under-voltage type if deemed necessary. However, the shunt trip has the disadvantage that it may fail to trip the circuit breaker under certain circumstances in the case of a feeder short circuit, due to drop in voltage. It is also an open-circuit device which is not as reliable for tripping purposes as a closed-circuit device. On the other hand, the under-voltage type may trip the circuit breaker due to drop in voltage in the case of a secondary network short circuit close to the transformer when it is desired to hold the load. This, however, would not be as serious as a failure to open a feeder short circuit.

The closing of the circuit breaker may be performed electrically either by an a-c. solenoid or by an a-c. motor. The closing solenoid is undoubtedly simpler and more sturdy but it is well known that an a-c. solenoid takes considerably more current. This is not objectionable, however, since the distribution transformers provide ample capacity for this purpose and the closing coils are in circuit only a fraction of a second. Motor-operated units are also somewhat more expensive in construction.

Evolution of the Automatic Network Relay

BY JOHN S. PARSONS[1]

Non-member

Synopsis.—Low voltage a-c. networks are coming into use as a means of providing a source of power having the dependability of the Edison d-c. network, and at the same time having the efficiency which can be obtained by supplying power from high voltage feeders with transformers located near the point of utilization. As in the case of d-c. networks, it is assumed that all trouble on the network itself will be burned clear without seriously interfering with any of the service. In case of trouble on a primary feeder or in one of its transformers, however, it is necessary to disconnect the feeder from the system. The a-c. network unit has been developed to connect these transformers to the network, and the "brains" of this unit, which is the automatic network relay, is described in this paper. This relay not only opens the network breaker whenever there is trouble in any of the high tension equipment or when the power feeds back into the high tension feeder but also recloses the breaker when conditions are restored to normal and the feeder is in condition to supply power to the network. The difficulties which were encountered and the relay characteristics necessary to overcome them are explained briefly.

The first installation of network units was made in April 1922 on single-phase, three-wire and two-phase, three-wire networks fed by three-phase, 2750-volt primary feeders. Since that time numerous improvements have been made and new designs created to extend the field of application, but the same general scheme of operation has been retained.

The automatic network relay is now past the experimental stage, approximately 1000 of them having been in service for some time. The probable future development of the network relay based upon operating experience to date is pointed out. Attention is called to the close relation existing between the operating characteristics of the automatic network relay and the characteristics of the system on which it is to be installed.

* * * * *

THE advantages of some form of a-c. secondary network distribution system, the chief of which are continuity of service and the ability to use higher voltage primary feeders, have long been recognized. It is only within the last few years, however, that the necessary control and protective apparatus for such a system has been developed. This apparatus, known as the a-c. automatic network unit, consists of an electrically operated carbon circuit breaker controlled by one or more induction type relays. The operating requirements of such a relay are discussed in detail in a companion paper[2] to this one.

It is proposed to give here the history of the development of one type of automatic network relay and to explain how the present network relays meet the various operating requirements.

While one or two installations have been made using reverse power or directional relays, such as are used for transmission line protection, for tripping network breakers when a fault occurs on a primary feeder or in a transformer, they cannot be considered automatic network relay installations. These, however, are of interest in that they have demonstrated that relays of the induction type, which are ordinarily installed in substations where they can be easily and frequently inspected, will operate satisfactorily in man-holes without any change in design. The automatic network relay not only controls the opening but also the closing operation of the network breaker. It is this fact that has made the design of the relay a much more difficult problem than that of most relays. The reverse current opening and automatic synchronized reclosing features which have been embodied in the network relay make the network circuit breaker a reverse power tripped breaker which can be remotely controlled from the station, without the use of pilot wires, merely by opening and closing the primary feeder breaker.

The first network relays were designed and placed in service on single-phase, three-wire lighting and two-phase, three-wire power networks in April 1922. These networks were fed by three-phase, 2750-volt primary feeders from the substation. Since the general scheme employed in these first automatic network units has been followed in future developments, the evolution of the network relay can be more easily followed and understood if a description of it is given at this point.

Fig. 1 shows a schematic diagram of connections for the first single-phase, three-wire network unit. The relay was an induction relay of the double contact type. The single-pole double throw contacts acted through the mechanism relay to control the operation of the breaker. The moving contact was held against the contact marked C by a spring when the relay became de-energized. This was essential in order to be able to start up a dead network. With the moving contact in this position a circuit was established from the left side of the line through the mechanism relay coils, the moving contact, and the stationary contact C to the other side of the line. This caused the core of the mechanism relay to pick up when the transformer was energized and to close the auxiliary switch A. The closing of this switch energized the closing coil, thus closing the breaker. The closing coil circuit was opened by the pallet switch B as soon as the breaker latched in a closed position so that this coil was energized only during the instant the breaker was being closed. In order to open the breaker, the moving contact of the relay had to move from position C to position O. The breaking of the contact at C place resistor R in series with the mechanism relay coils. The value of this

1. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

2. "Operating Requirements of the Automatic Network Relay", by W. R. Bullard.

Presented at the New York Regional Meeting of the A. I. E. E., New York, N. Y., November 11-12, 1926.

resistance was such that with it in circuit the mechanism relay core would not pick up, but once picked up it would remain in that position. When the moving contact was made with stationary contact O due to a flow of reverse energy, the mechanism relay coils were shunted, leaving the resistor R connected across the line. The shunting of its coils caused the core of the mechanism relay to drop and to trip the latch that held the breaker closed.

The operating forces in the relay were obtained by means of three sets of coils. The flux produced by the potential coil, shown connected across the secondary of the distribution transformer on the network side of the breaker, combined with the flux of the phasing coils to produce a closing torque in the relay and with

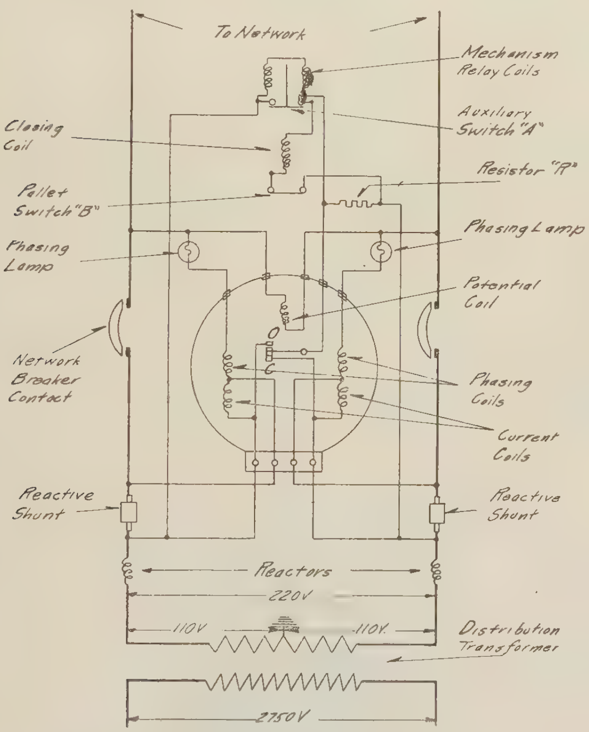

FIG. 1—DIAGRAM OF CONNECTIONS FOR THE FIRST SINGLE-PHASE THREE-WIRE NETWORK UNITS

the flux of the current coils to produce an opening torque in the relay. It was necessary therefore for the potential coil to be energized at all times in order to secure an electrical torque in the relay. This constituted an important reason for connecting the potential coil on the network side of the switch. When a primary feeder was de-energized at the substation the network breakers on this feeder were opened by their relays due to the flow of reverse energy. Once the breaker was open, the phasing coils, in conjunction with the potential coil, gave a very strong opening torque to keep the moving contact of the relay in position O. If, however, the potential coil had been connected on the transformer side of the breaker, it would have received practically no voltage, since it would have been shunted by the distribution transformer, the impedance of which was very low compared to that of the potential coil. Under this condition, there would have been no torque to keep the moving contact of the relay in position O, and therefore since it would have moved to position C by spring action the synchronized reclosing feature of the relay would have been destroyed. This means that when the primary feeder was next energized the network breaker would have reclosed immediately irrespective of the voltage across it.

The design of the phasing coils, one of which was connected across each pole of the network breaker, had to be such that the relay would operate to close the breaker with approximately one volt of the proper phase relation existing across the contacts of the breaker. When the network was energized, however, and the feeder breaker at the substation was open there was full line to ground potential across the open contacts of the network breaker and consequently across each phasing coil of the relay. With the possibility of the transformer voltage being reversed due to an error in making connections, twice normal voltage across each phasing coil may occur. In order to prevent burning out of the phasing coils at these high voltages, a small tungsten filament lamp commonly called the phasing lamp was placed in series with each coil. Since tungsten has a large positive temperature coefficient of resistance, the lamp automatically inserted resistance in the circuit as the voltage across the circuit increased.

When a primary feeder breaker is opened at the substation the transformer connected to that feeder becomes magnetized from the network. This flow of exciting current from the network to the transformer should be sufficient to cause the relay to operate to open the network breaker. The fact that the current coils, acting in conjunction with the potential coil, should produce sufficient torque to operate the relay on this relatively small value of current and must also be capable of being subjected to the full load current of the transformer continuously without overheating, made it necessary to connect them across reactive shunts placed in the secondary leads of the distribution transformer. At very small currents the reactance of the shunts was comparatively high and consequently a large part of the line current passed through the current coils of the relay. Due to the saturation of the magnetic circuits of the shunts, as the line current increased the reactance of the shunts decreased. The percentage of the line current passing through the relay therefore decreased rapidly and in this way the current in the current coils of the relay at full load was limited to a value which would not cause excessive heating.

It is not only essential that the magnitudes of the currents and voltages on which the network relay must operate be considered but their phase positions must also be taken into account in order to secure satis-

factory performance. Fig. 2 shows the operating characteristics of the relay for various magnitudes and phase positions of voltage and current. The network voltage, which is the voltage on the network side of the breaker, is used as a reference voltage in plotting these curves since it is the voltage impressed across the potential coil of the relay. The closing Curve No. 1-*A* shows the closing characteristics of the first network

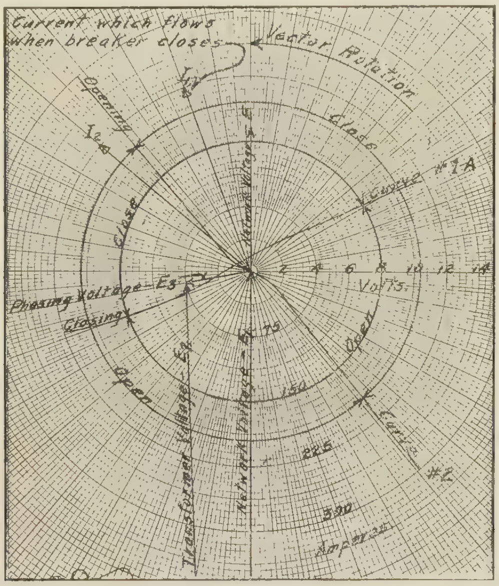

Fig. 2—Curves Showing the Operating Characteristics of the First Network Relays

relay over the range of phasing voltages on which it ordinarily operated. Lines drawn from the origin to this curve represent in magnitude and phase position voltages across the open network breaker and consequently across the phasing coils of the relay which produced a balanced condition in this relay. Any phasing voltage of such magnitude and phase position that it crossed the closing curve into the zone marked "close" produced a torque in the relay which caused it to operate to close the network breaker. If the phasing voltage did not cross the closing curve, however, the phasing coils produced a torque which caused the moving contact of the relay to move to position *O* and thus prevented the breaker from closing. Lines drawn from the ends of the phasing voltages to the ground potential point of the network voltage vector E_1, which could not be shown in Fig. 2 because of the scale used, represent the voltages of the unloaded transformer.

The opening characteristics of the relay are shown by Curve No. 2, Fig. 2. Lines drawn from the origin to this curve represent in magnitude and phase position, with respect to the network voltage E, the line currents that were necessary to produce a balanced condition in the relay. If the line current was increased slightly so that it just crossed the opening curve into the zone marked "open," the relay operated to open the network breaker. Line currents that did not cross the opening curve produced a torque in the relay in the closing direction which held the moving contact against the stationary contact C.

The current which flows after the network breaker closes lags the phasing voltage,—that is, the voltage across the breaker before it closed,—by an angle approximately equal to the impedance angle of the system. By impedance angle of the system is meant the angle between the resistance and impedance vectors of the loop consisting of the feeder being connected to the network, together with its regulator and particular transformer being considered, in series with the low tension mains and all parallel transformers, primary feeders, and regulators connected from the same bus to the network. This angle remains almost constant on systems having high impedance transformers and large secondary mains if the spacing of the transformers is not too great.

The relays having operating characteristics as shown in Fig. 2 were installed on a system using two single-phase induction regulators per feeder with their rotors mechanically connected and standard distribution transformers with reactors in the secondary leads which are equivalent to high impedance transformers. With the system impedance angle of approximately 80 deg. the relays operated satisfactorily. The reason for this can be seen by referring again to Fig. 2. The phasing voltage, E_3, which could readily be obtained by having the regulators on the incoming feeder in the buck position, caused the relay to close the network

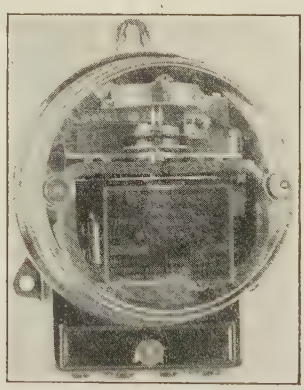

Fig. 3—The First Automatic Network Relay to be used for Controlling Network Units on Three-Phase, Four-Wire Networks

breaker. As soon as the breaker closed, a current, I_1, lagging behind voltage E_3 by about 80 deg., flowed through it. Since this current did not cross the opening curve but fell in the area marked "close," the current coils of the relay produced a closing torque and maintained the breaker in the closed position. Any phasing voltage leading the network voltage which caused the relay to close the breaker caused a current to flow after it closed which produced a closing torque

in the relay, because the angle between the opening and closing curves was less than the impedance angle of the system.

On the two-phase, three-wire network previously referred to, a polyphase network relay was used. This relay consisted of two electrically independent elements mechanically connected so as to control one set of single-pole, double throw contacts. The coils of one element were connected to one of the two phases and those of the other were connected to the other phase. Since in this case the normal voltage to ground was 220 volts, two phasing lamps were used in series with each phasing circuit instead of one. Aside from these differences the general scheme and operating characteristics were essentially the same as those described above for the single-phase relay.

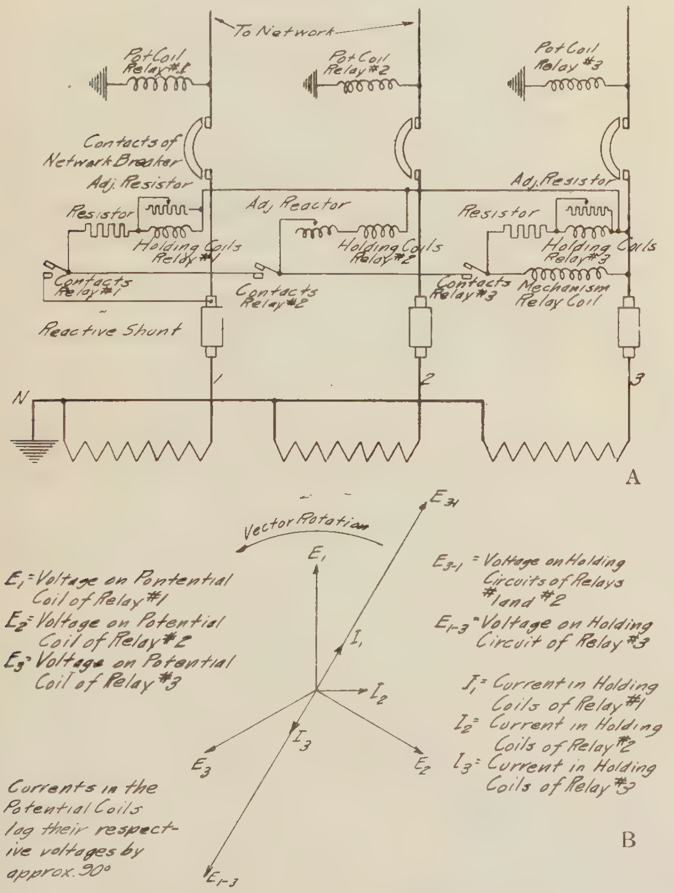

Fig. 4—Connections for the Holding and Potential Coils of the Network Relays used on the First Three-Phase, Four-Wire Network Units

The next step in the network relay development was the designing of a relay, Fig. 3, which could be used on a three-phase, four-wire network as well as on a single-phase, three-wire network. Because it was found that the time required for the double contact relay to open the network breaker was considerably longer than is desirable in case of a primary cable fault, it was decided to abandon the double contact feature. The use of a single set of contacts made it necessary to place an additional set of coils in the relay on the same poles of the electromagnet as the phasing and current coils. These coils, known as the holding coils, were connected in series with the contacts of the relay and in conjunction with the potential coil, acted to produce a positive torque to hold the contacts closed once they were made. In order to open the contacts of the relay the current coils had to produce sufficient torque to overcome this holding torque. In this way the relay was prevented from tripping the breaker when no current was flowing and the value of reverse current required to open the relay contacts could be adjusted by adjusting the amount of this holding torque. The holding coils, of course, had no effect on the operation of the relay except when the contacts were closed.

The holding coils of the three relays of this type required on a three-phase, four-wire network all had to be connected across one line voltage, as shown in Fig. 4A, since only one set of contacts per relay was used. This figure for simplicity shows a schematic diagram of only the holding and potential circuits of the relays. It may be noted that both relays No. 1 and No. 3 had fixed resistors in series with their holding coils and adjustable resistors in parallel with them. Practically all of the impedance of the holding circuits was in these fixed resistors. Changing the adjustable resistors to adjust the amount of holding torque had practically no effect on the amount of current that flowed in the circuit but merely changed the relative amounts of current in the two parallel paths. Relays No. 1 and No. 3 were identical in every respect except for the polarities of the holding circuits. The polarities of the two had to be different in order to secure the proper direction of torque in the two relays. This can readily be seen by referring to Fig. 4B, wherein it is shown that the three potential coil voltages with which the holding coils had to act to produce a torque were 120 deg. out of phase. If the holding circuit of relay No. 2 had been similar to that of either relay No. 1 or relay No. 3, the current in the holding circuit would have been either in position I_1 or position I_3, either of which would have been approximately 90 deg. out of phase with the potential coil voltage, and no torque would have been produced by the holding coil. From this description it can be seen that all three of the relays were different and had to be mounted in their proper positions on the network unit in order to function correctly.

The other differences between this single contact relay and the double contact relay can best be seen by referring to Fig. 5. The scheme was essentially the same as the one using the double contact relay except for the points already mentioned. There was, however, one other point of sufficient importance to mention here. The single contact relay had its two phasing coils connected in series and in series with the phasing lamp across one pole of the breaker instead of having one

phasing coil and lamp across one of the contacts of the breaker as in the previous scheme. The impedance of the phasing circuit of this relay was therefore considerably more than that of the double contact relay. Since the distribution transformer is connected to the network through the phasing circuit when the breaker is open, the impedance of this circuit should be as large as possible so as to keep down the voltage induced in the primary of the transformer, when the feeder is deenergized to a very small value.

By using only the two outer poles of the unit shown

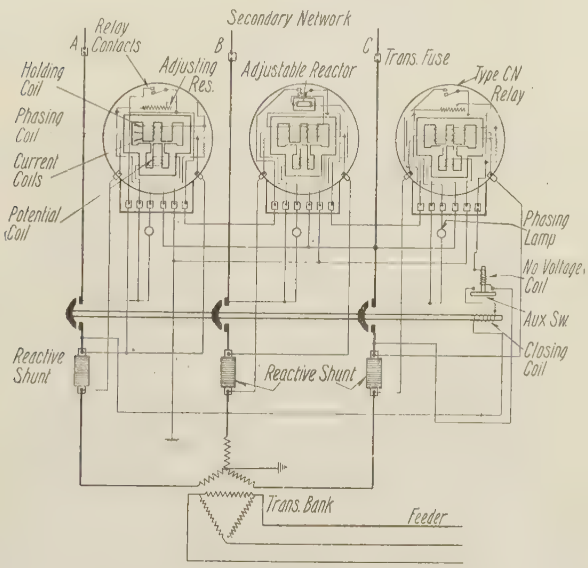

FIG. 5—DIAGRAM OF CONNECTIONS FOR THE FIRST THREE-PHASE, FOUR-WIRE NETWORK UNIT

in Fig. 5 and blocking the contacts of the No. 2 relay closed or removing the relay altogether and tying together the connections which go to its contacts, the unit can be used on a single-phase, three-wire network. Quite a large number of these units are now operating on such a network.

Since this single contact relay was designed for operation on the system on which the double contact relays were installed, its operating characteristics were made similar to those shown in Fig. 2. Soon after these relays were installed a change was made in the network on which they were placed which decreased the impedance angle of the system. Since the characteristics of the relays were no longer correct for the system on which they were applied, trouble was encountered due to some of them pumping; that is, alternately opening and closing their contacts. This action can best be understood by referring again to Fig. 2. Suppose that for some reason the regulators on one feeder buck the voltage down below that of the other feeders, thus causing a leading current, such as I_2, to flow in the feeder. This would cause the network breaker to open. A voltage E_3 of the proper magnitude and phase position to cause the relays to close their contacts would then exist across the breaker and it would immediately reclose. This action would continue until the unit failed or until conditions on the circuit changed. The same action would result were the primary feeder breaker closed and the phasing voltage E_3 produced across the open network breaker by the feeder regulators and the load on the other feeders. This pumping condition was overcome by changing the operating characteristics of the relays. The opening curve was rotated approximately 30 deg. in the counter-clockwise direction which again made the angle between the opening and closing curves less than the impedance angle of the system. A large number of these relays are now in service and are giving almost perfect performance.

The number of relays required on a fair sized three-phase network is large compared to the number of substation relays required to protect the network. For instance, a six-feeder network having fifteen transformer banks per feeder would require 270 network relays as compared with 24 overcurrent relays in the substation, assuming that both line and ground relays are used. It can be seen from this that the maintenance of the network relays on a system presents a problem which cannot be ignored. It was largely because of this that it was decided to abandon

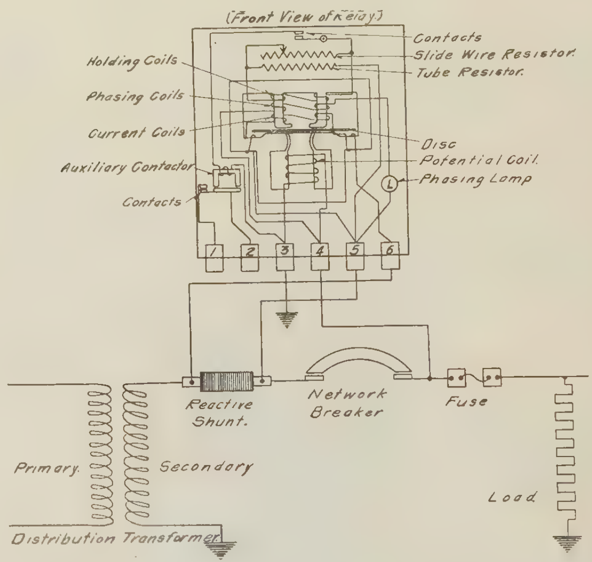

FIG. 6—GENERAL ARRANGEMENT OF THE INTERNAL AND EXTERNAL CONNECTIONS OF THE PRESENT NETWORK RELAY

the use of the single-phase, watthour meter case, change the holding circuit so as to make all relays for use either on single-phase, three-wire or three-phase, four-wire systems exactly alike, and make a number of more or less minor changes mostly of a mechanical nature. The relay was completely redesigned and everything possible was done to reduce the amount of maintenance required to an absolute minimum and to facilitate the necessary maintenance. The new network relay is mounted in a very shallow rectangular case with a glass cover. This makes all parts of the

relay easily accessible for inspection. There is much more room in this rectangular case although it does not require any more space for mounting on the panel of the network unit. This has made it possible to mount the phasing lamp, which is really a part of the relay, inside of the relay case where it is less likely to be broken. In all previous designs the phasing lamp or lamps were mounted as separate units on the panel of the breaker.

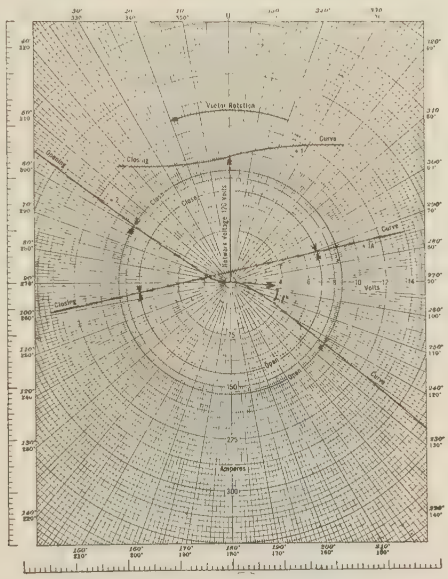

Fig. 7—Curves Showing the Operating Characteristics of a Network Relay for use on Systems where the Exciting Current of the Transformers Predominates Over the Charging Current of the Feeder

In order to design the holding circuit so as to make the network relay a strictly single-phase unit it was necessary that the contacts of the relay be double-pole single-throw with the additional requirement that the contact which makes first must also break first. Since no reliable way could be found to accomplish this mechanically, the same result was obtained by connecting the operating coil of a small auxiliary contactor in series with the contacts of the relay, the holding coil, and the series resistor. The holding circuit of the relay is now connected from line to ground on the transformer side of the network breaker. The contacts of the auxiliary contactors which are independent of all other circuits in the relay are used to control the operation of the mechanism relay which in turn controls the operation of the breaker. It has been found possible to arrange the circuits in the relay so as to reduce the number of terminals from eight to six. The arrangement of the circuits in the relay and the way in which they are connected to the network breaker are shown in Fig. 6. This figure shows only one relay and one pole of the network breaker. The other relays, however, are connected to the other poles in exactly the same way. The contacts of the auxiliary contactors in all relays are connected in series with the mechanism relay coil across one of the line voltages. It is necessary that the relay contacts be connected in series both to insure opening the breaker in case of a fault and to prevent pumping because of unbalanced voltage conditions. It will be noted that it is necessary for only one relay to open its contacts to open the breaker but the contacts of all relays must be closed before the breaker will close.

The operating characteristics of the relay, which are very similar to those of the first single contact relay after it was modified, are shown in Fig. 7. These relays are operating satisfactorily on systems having 2750- and 4000-volt feeders and using single-phase induction feeder regulators. Relays having operating characteristics such as those shown in Fig. 7, however, when installed on systems having high-voltage primary feeders, such as 13,200 volts or higher, may not open when the feeder to which they are connected is de-energized at the station. This is because the relays must function to open the breaker on a reverse current which is the vector sum of the feeder charging current and the exciting current of the transformers connected to the feeder. The charging current may predominate and cause the resultant current to take some such position as I_1, Fig. 7, and since it does not cross the

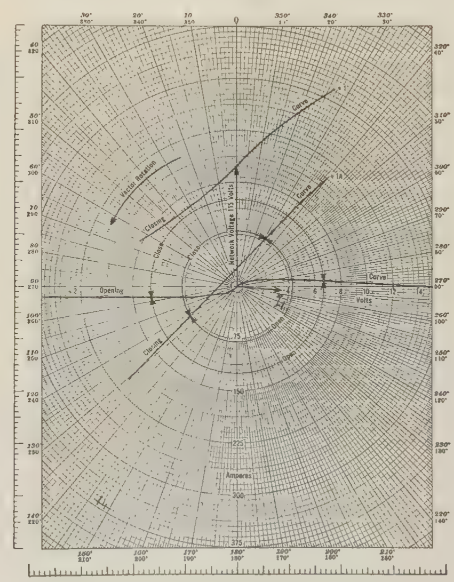

Fig. 8—Curves Showing the Operating Characteristics of a Network Relay for use on Systems Where the Charging Current of the Feeder Predominates Over the Exciting Current of the Transformers

opening curve, the current coils of the relays produce a positive closing torque to hold the network breakers closed. On the first network system having 13,200-volt primary feeders the current on which the network relays had to open was almost a 90-deg. leading reversal, and in order to make them function properly it was necessary to change their operating characteristics by rotating both the opening and closing curves in the

counter-clockwise direction to the position shown in Fig. 8. Current I_1 on which they had to operate now crosses the opening curve into the zone marked "open" and the relays function as they should. In order to have one relay which could be used on systems having either high- or low-voltage feeders or both, the network

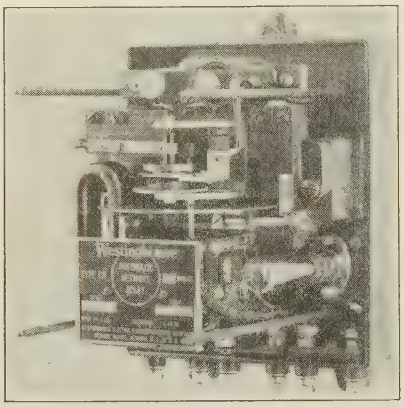

Fig. 9—The Present Automatic Network Relay

relay was modified so that either the characteristics shown in Fig. 7 or those shown in Fig. 8 could be obtained merely by shifting the position of a link on a connector block in the relay.

The present automatic network relay shown in Fig. 9

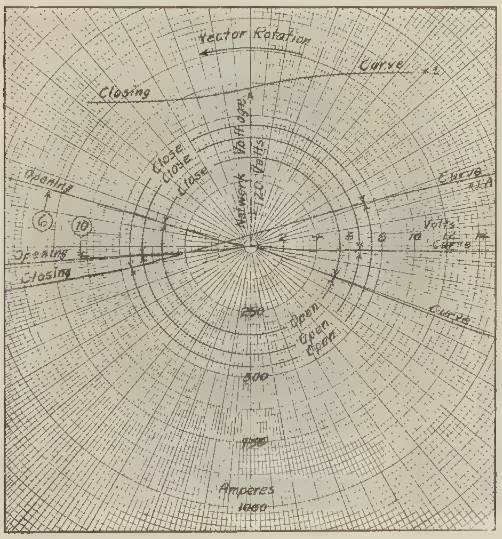

Fig. 10—Curves Showing the Operating Characteristics of the Present Network Relay Which is Applicable to Systems Having Either High- or Low-Voltage Primary Feeders.

is almost identical with the first rectangular case relay previously described except for its operating characteristics. The operating characteristics of the relay are shown in Fig. 10. Two opening curves are provided, instead of using the one curve marked 10, so as to secure maximum sensitivity in the relay and thus insure its opening on small values of reverse current either leading or lagging. When the relay is installed on systems where the transformer magnetizing current predominates over the cable charging current to produce a lagging reversal, opening curve No. 6 should be used. This characteristic is obtained by placing the two-current tap screws in the No. 6 holes of the connector block in the relay. Should the charging current of the primary cable predominate to give a leading reversal, the No. 10 opening curve should be used. Since the angle between the closing and opening curve, regardless of which opening curve is being used, is small, the relay will operate on any system where the phasing voltage leads the network voltage. This is, of course, assuming that the impedance angle of the system is greater than the angle between the opening and closing curves of the relay which will be true in practically all cases. Since, on systems using polyphase regulators or two single-phase regulators connected open-delta, the phasing voltage may lag the network voltage, the relay may

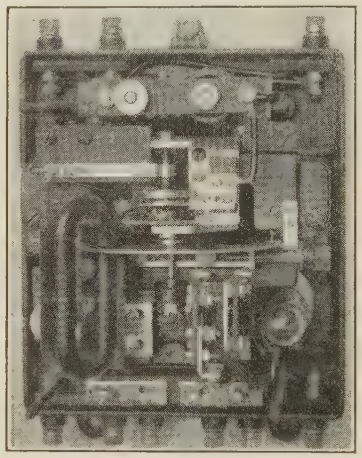

Fig. 11—Relay for Controlling Network Unit for use on Two-Phase, Five-Wire or Single-Phase, Three-Wire Networks.

pump unless steps are taken to limit the angle of lag. The angle by which the phasing voltage may lag the network voltage in any given case without causing pumping will be determined by the impedance angle of the system. It will be noted that in the present relay the opening curve is rotated without affecting the closing curve. This is desirable as it allows the closing curve to be placed in such a position that the relay will not close its contacts if, when making repairs, the phases on the circuit to which it is connected have been accidentally crossed.

In addition to the adjustment for the opening characteristics, the relay is provided with an over-voltage closing and a reverse current opening adjustment. These adjustments, especially the over-voltage adjustment, should be set as high as can possibly be done and still secure satisfactory operation, because this will increase the stability of the operation of the relay.

The reverse current adjustment is primarily for the purpose of insuring that all relays function alike when opening on small values of reverse current.

A relay was recently developed for use on a two-phase, five-wire network. Two two-pole network breakers will be used with each bank of transformers, one being connected in each phase. The relay just discussed could have been used for this application, but since two relays would have been required to control each breaker and as space was an important item, it was decided to design a relay so that only one would be required to control each breaker. This relay, Fig. 11, commonly referred to as a two-phase re'ay, is really a single-phase device and is very similar in construction and operating characteristics to the present standard network relay. It differs from the standard, however, in that it has two phasing and two current circuits similar to the first double contact network relay. One phasing and one current circuit are connected across each pole of the network breaker.

Experience with the design and operation of network relays all points toward the desirability of having a relay which has operating characteristics that make it applicable to any type of network system. Enough work has been done along this line to show that it is possible to produce such a universal network relay having adjustable operating characteristics. Such a relay would have to be adjusted to fit the characteristics of the system on which it was to be installed. These adjustments, instead of simplifying the relay, will add somewhat to its complication. Because of this, the ideal network relay would be one having fixed characteristics of such a nature as to make it universally applicable to network systems. Such characteristics are theoretically possible and considerable work has already been done which indicates that such a relay is entirely practical.

The automatic network relay is now past the experimental stage, and there are at the present time approximately 1000 network relays, such as have been described in this paper, installed and operating satisfactorily on a number of network systems. From the above discussion it can be seen that the operating characteristics of the automatic network relay and the characteristics of the system on which it is to be installed are very closely related. This relation must be fully understood and appreciated both by the designers of low-voltage, a-c. network systems and the designers of network relays in order to secure the most satisfactory operation of the system as a whole.

A Graphical Determination of Ampere-Turns
for Trapazoidal Teeth Sections

BY J. F. CALVERT[1]

THIS method applies to rotating electrical machines having rectangular slots and trapazoidal teeth sections. If any apparent tooth density at the widest section be assumed, then a quick and reasonably

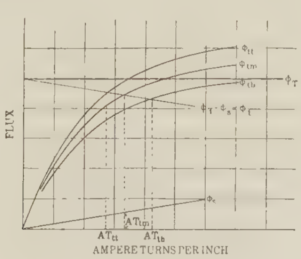

FIG. 1

accurate determination of the corresponding no-load field ampere-turns may be made.

The proof of the method is as follows:

For the tooth pitch under the center of the pole, it is assumed that the surfaces at right angles to the flux lines are cylindrical and coaxial with the center line of the shaft.

In Fig. 1, curves are plotted for one inch in an axial direction. Flux is plotted as ordinates, ampere-turns per inch as abscissa, and the following notation is used:

The first subscript

- t = in the iron (or tooth)
- s = in the non magnetic parts (or slot)
- T = total in the iron and non magnetic parts at any section.

The second subscript

- t = at the tip section
- m = at the mid section
- b = at the base section
- $a\,p$ = apparent (at the widest section).

The main symbols

- Φ = flux
- B = flux density in the iron
- $A\,T$ = ampere turns per inch
- W = tooth width
- a = cross sectional area.

Primes indicate the stator.

- B_{ap}' = apparent tooth density at the base of the stator's teeth
- B_{ap} = apparent tooth tip density for the rotor.

1. Design Engineer, Westinghouse Electric and Mfg. Co.

At any section

$$\Phi_t = \Phi_T - \Phi_s$$
$$\Phi_t = B_t\, a_t$$
$$\Phi_s = 3.19\, a_s\, A\, T \qquad (1)$$

The area, a_s, will be calculated at the mid section and assumed to be the same at all sections.

The ampere-turns per inch at the tip, mid and base sections are shown in Fig. 1 as $A\,T_{tt}$, $A\,T_{tm}$, and $A\,T_{tb}$, respectively. If the ordinates of the curves in Fig. 1 are all divided by a_{tt}, then new values are obtained so that for the rotor

$$\frac{\Phi_T}{a_{tt}} = B_{ap} \qquad (2)$$

$$\frac{\Phi_{tt}}{a_{tt}} = B \qquad (3)$$

$$\frac{\Phi_s}{A_{tt}} = 3.19\,\frac{a_s}{a_{tt}}\,A\,T \qquad (4)$$

$$\frac{\Phi_{tm}}{a_{tt}} = B\,\frac{W_{tm}}{W_{tt}} \qquad (5)$$

$$\frac{\Phi_{tb}}{a_{tt}} = B\,\frac{W_{tb}}{W_{tt}} \qquad (6)$$

If instead of the actual curves indicated by equations (3) to (6), a new set of curves are plotted as

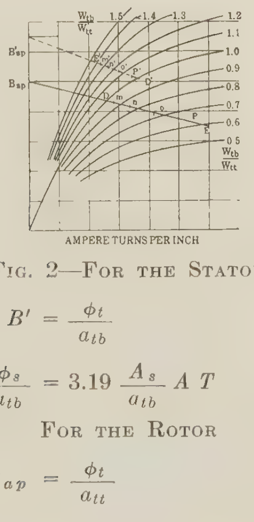

FIG. 2—FOR THE STATOR

$$B' = \frac{\phi t}{a_{tb}}$$

$$\frac{\phi_s}{a_{tb}} = 3.19\,\frac{A_s}{a_{tb}}\,A\,T$$

FOR THE ROTOR

$$B_{ap} = \frac{\phi t}{a_{tt}}$$

$$\frac{\phi_s}{a_{tt}} - 3.19\,\frac{a_s}{a_{tt}}\,A\,T$$

shown in Fig. 2, then the ampere-turns may be calculated as follows.

For the rotor

Assume B_{ap}, and draw $B_{ap} - E$ so that according to the scales used the ordinate divided by abscissa $= 3.19\,\frac{a_s}{a_{tt}}$. Extend $B_{ap} - E$ only to the curve indicated by $\frac{W_{tb}}{W_{tt}}$ which corresponds to the actual case under consideration. Average the ampere-turns per inch, $m - n - o - p$, and multiply by the length of the tooth in inches to obtain the ampere-turns for the tooth.

For the stator

Calculate B_{ap}', draw $B_{ap}' - D'$, average $m' - n' - o' - p'$ and multiplying by the length of the tooth.

When one value has been found, it is only necessary to assume new apparent densities and to shift a triangle parallel to $B_{ap} - E$ or $B_{ap}' - D'$ to obtain the new values of ampere-turns per inch.

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RESULTS ATTAINED THROUGH ENLARGED ELECTRIFICATION

In earlier publications of the department, such as "Super Power Studies in Northeastern Section of the United States," great emphasis was laid upon the possibilities of the elimination of waste which lay in the transformation of the power industry through the discoveries in the science of long-distance transmission and their application by large central generating plants feeding large system and their interconnection with each other. Such savings lay in the greater economy in power production by saving fuel and labor by the larger central plants; the reduction of the amount of reserve equipment required; a better average load factor, and thus less equipment, through pooling of the daily and seasonal fluctuations, together with wider diversification in use; more security against interruption; better utilization of water power by applying it to base loads while making steam carry the peaks; utilization of secondary power from the seasonal flow of streams to the partial relief of steam; savings in industry by replacement of factory steam plants, the increased day load being supplied by the same generating equipment as night load for cities; the larger application of power in replacement of factory labor; and likewise the economies in the household and farm application of power.

All of these anticipated values have been realized in an extraordinary degree through the initiative and genius displayed in the electrical industry. The electrical generating capacity in the country has increased from 14,280,000 to 23,840,000 kilowatts in five years, an increase of 67 per cent. Although 66 per cent of our energy output is from fuel, the development of water power has been most active.—(From the Annual Report of the Secretary of the Dept. of Commerce.)

Fifty Years' Progress in Electrical Communications[1]

BY M. I. PUPIN

STEPHEN GRAY AND FRANKLIN

IT is now two hundred years since Stephen Gray discovered that an electrical charge will move with great rapidity along certain substances called conductors today. The motion of electricity began then to attract the attention of the natural philosopher, and it became the subject of many scientific researches, particularly after Franklin had demonstrated that lightning is a motion of electricity. There is no doubt that many a scientist of Franklin's time associated with the destructive power of lightning something resembling the destructive power of a projectile; something endowed with an irresistible momentum. But who would have dared to suggest in those days that moving electricity just like moving matter had a momentum? Nobody suspected in those days that the history of the electrical science of the first half of the nineteenth century would be a record of the gradual evolution of this electrical momentum concept. Oersted's discovery in 1819 of the magnetic field of force accompanying the motion of electricity marks the first step in the progress of that evolution.

MAXWELL'S CONCEPT OF THE MOMENTUM OF MOVING ELECTRICITY

Faraday was the first to recognize that the magnetic field accompanying moving electricity, and every other magnetic field, gave to the space occupied by it a new physical state; he called it the electrotonic state, and saw in the electrical forces of induction which he had discovered a manifestation of the electrical reaction opposing the change of the electrotonic state. Finally the genius of Maxwell succeeded in revealing in Faraday's electrotonic state the momentum of moving electricity. This is one of the two fundamental concepts in Maxwell's electromagnetic theory, and it was destined to play the leading part in the development of the electrical science as well as of the electrical art of telegraphy and telephony. Maxwell showed that the magnetic flux associated with moving electricity is the momentum of that motion, and that the electrical forces discovered by Faraday were the reactions opposing the change of that momentum in accordance with the law of inertia which has the same mathematical form as that which Newton had formulated for moving matter. From that point of view Maxwell may be called the Newton of the science of moving electricity.

There was, however, an obvious difference between Newton's momentum of moving matter and the momentum of moving electricity; whereas the momentum of moving matter is located in the parts of space where that motion actually takes place, the momentum of moving electrical charges extends beyond the places where the electrical charges are moving; it is everywhere where the magnetic flux is; hence, Maxwell's many efforts to detect in the surrounding space hidden motions coupled to the moving charges. Motions of Faraday's tubes of force attached to the charges performed satisfactorily the functions which Maxwell attributed to these hidden motions, and he endowed the motion of these tubes with a momentum. This, broadly stated, completed the foundation of Maxwell's electromagnetic theory.

Faraday's discoveries in the field of electromagnetic induction are the source to which the evolution of Maxwell's concept of the electrokinetic momentum traces its origin, but the early developments in the science and the art of electromagnetic telegraphy contributed very much to this evolution. The electromagnetic telegraph was invented by Joseph Henry and operated at Princeton in the same year in which Maxwell was born. It requires no stretch of imagination to see in those contributions from telegraphy a stimulating tonic to Maxwell's efforts to interpret dynamically Faraday's discoveries. A brief description of these contributions will be helpful.

MAXWELL AND JOSEPH HENRY

The field of magnetic force accompanying a given motion of electrical charges is determined by Ampère's law, but the field of magnetic flux is not; it depends upon the magnetic permeability of the medium in which the magnetic field is located; it is proportional to it and to the magnetic force. Since, according to Faraday's law, the variation of the magnetic flux and not that of the magnetic force is the measure of the inertia reaction against the change of that motion, it is obvious that magnetic permeability increases that load; it adds more inertia to moving electricity. This, broadly speaking, was Maxwell's reasoning in his gradual evolution of the electrokinetic momentum concept. In this he was undoubtedly aided by Joseph Henry's historical experiments which led to the discovery of self-induction. They are the earliest and the most striking exhibition of the electrical reaction against the change of the magnetic flux interlinked with the magnetizing coils of Henry's great electromagnets; moving electricity was never, up to that time, more heavily loaded than the electricity moving through these coils.

The man who was the first in the field of research

1. The Presidental Address, delivered December 27, 1926, by Professor M. I. Pupin, retiring president of American Association for the Advancement of Science.

dealing with electromagnets and their application to telegraphic signaling was destined to make the discovery of the reaction called self-induction. Every flash of the interrupted magnetizing current announced that reaction. The man who first interpreted these flashes correctly was Joseph Henry and he may be justly considered not only the discoverer of self-induction, but also the inventor of the best means of transforming electrical into magnetic action and of transmitting it to a distance for signaling purposes. The expression "magnetic action" is used here purposely; it is Faraday's favorite expression. Telegraphic receiving instruments in those days operated by magnetic force; that was the force transmitted from one telegraph station to the other; this in all probability suggested to Faraday the expression "magnetic action."

Transmission of Magnetic Action

The laws of propagation of magnetic action were not yet clearly defined in Henry's mind when he sent his first telegraphic messages, neither were they thirty years later in Faraday's mind, although he had thought a great deal about it, and even encouraged his young disciple Maxwell to think about it. The encouragement came like a godsend to this mathematical tripos youth who had just distinguished himself at Cambridge. It came at the very time when William Thomson, the late Lord Kelvin, had succeeded in solving the problem of telegraphic transmission over submarine cables, and Kirchhoff, the discoverer of spectrum analysis, had amplified Thomsons's solution so as to include transmission over ordinary telegraph wires. Thomson had neglected in his solution the inertia reaction of moving electricity but Kirchhoff had not, and this resulted in his mathematical proof that the velocity of propagation of signals over telegraph wires was equal to the velocity of light. This remarkable result made, as is wellknown, a profound impression upon young Maxwell's mind and gave a new meaning to Faraday's intuition that, as he wrote to Maxwell in 1857,

" . . . the time of magnetic action . . . must probably be short as the time of light; but the greatness of the result, if affirmative, makes me not despair."

It was nothing less than the greatness of the result which Maxwell aimed at, and guided by Faraday's suggestion and Thomson's and Kirchhoff's mathematical analysis he, in less than eight years, obtained the result, and revealed the general law of propagation of magnetic action covering Thomson's and Kirchhoff's problems as special cases. When in 1865 Maxwell published his great essay "A Dynamical Theory of the Electromagnetic Field" he not only demonstrated that magnetic action moves through space like light, but moreover, he supplied the telegrapher with new knowledge which would enable him to solve every transmission problem in the art of electromagnetic telegraphy of those days. Henry's invention of the magnetic telegraph and the resulting telegraphic transmission problems, solved thirty years later by Thomson and by Kirchhoff, guided Maxwell in his great endeavors and in return for this precious service he supplied the telegraphic art with a trusty guide in all its future endeavors.

Maxwell and the Telegraphists

The very natural question arises, did the telegraphic art take full advantage of the science to the creation of which it had contributed so generously and which was ready to render generous service in return? The answer must be in the negative. The earlier history of the Faraday-Maxwell electromagnetic theory tells an instructive story concerning this. The telegraphist was more concerned about the apparatus at the sending and at the receiving end of the signaling conductors than about the fate of the signal during its journey between these two ends. This is particularly true of submarine cable transmission. When Thomson first attacked the submarine cable problem in the early fifties he had in mind slow speed signaling over transatlantic cables and neglected the inertia reaction of the moving charge; it is small when the momentum of the moving charge varies slowly as in the case of slow cable signaling. Besides, the magnetic field of the moving charge seemed also to be very small, since the conducting copper core in the cable is very close to the conducting seawater. Under these conditions Thomson's theory gave satisfactory results, but the telegraphist jumped to the conclusion that this theory, the so-called Thomson Electrostatic Theory of Transmission, was universally applicable. He was not aware that Kirchhoff's theory of telegraphic transmission told a different story. Even so distinguished a theoretician in the telegraphic art as Heaviside had never heard of Kirchhoff's essay until nearly thirty years after its publication, and then he found fault with it on account of its lack of intelligibility. Nobody else had ever accused Kirchoff of this shortcoming. Maxwell caught Kirchoff's meaning readily, and found inspiration in it. True, the telegraphists found fault, but not with Kirchhoff; they never had heard of him. On the other hand they could not help hearing Heaviside's reproachful voice directed against the telegraphists, who were accused by him of worshiping a false divinity, the electrostatic theory of transmission. They answered the charge by finding fault with Heaviside's alleged lack of intelligibility, and so they paid no attention to either Kirchhoff or to Heaviside, who, as I just pointed out, had many years later rediscovered what was known to Kirchhoff and to Maxwell in 1857. This indifference on the part of the telegraphists was unfortunate but excusable, because their minds were polarized by their strong belief in the infallibility of Thomson's electrostatic theory, which had served them so well. Even Heaviside's profound learning, reinforced by cutting sarcasm and satire, could not shake that belief for many years. Those were the years of barren and somewhat bitter controversy, which did not advance the telegraphist's understanding

of the good things which Maxwell had in store for him. A splendid opportunity to illustrate one aspect of the Faraday-Maxwell electromagnetic theory by everyday experience in telegraphy was thus lost.

Telephony and the High Inductance Doctrine

Fifty years ago, when this lively controversy was started in England, a new method of electrical communications was born; Alexander Graham Bell invented the telephone, the practical application of which demanded a new type of electrical transmission engineering. The telegraphists trained in the school of Thomson's theory could not qualify, said Heaviside, alleging that in their analysis of the transmission of magnetic action they ignored the inertia reactions of moving electricity. Heaviside was right, but he had no sufficient reason to feel highly provoked about it; Kirchhoff was as gentle as a dove when he pointed out that Thomson had neglected the inertia reaction of moving electricity. Heaviside's charge against the telegraphists was supported by the highest authority,—Maxwell's electromagnetic theory, in which the inertia reaction of moving electricity is one of the foundation pillars. But the weight of this authority did not add weight to Heaviside's attacks because there were in those days very few scientists in England or anywhere else who understood clearly Maxwell's meaning. Heaviside was certainly one of these chosen few, but his extraordinary mathematical exuberance obscured to the non mathematical mind of the telephone engineer his interpretation of Maxwell.

The momentum of moving electricity and its beneficial effects in the propagation of magnetic action, as Faraday called it, were already clearly visible in Kirchhoff's essay of 1857, and nothing was plainer than this beneficial action in Maxwell's description of electromagnetic transmission through absorptive media. Every herdsman's boy in my native village, instructed by practical experience, knew that sound is transmitted more efficiently through dense and hard ground and through water than through air. When the full meaning of Maxwell's electromagnetic theory first dawned upon me I thought of that knowledge I had gained on the pasture lands of my native village. The meaning of Maxwell's propagation constants, which I called figuratively magnetic density and electrical stiffness, reminded me immediately of the dense and hard ground through which the chums of my boyhood days and I transmitted sound signals. The physical reasoning concerning this simple matter appeared to me as being of the most elementary kind and not at all involved in complicated mathematical formulas. When energy is transmitted along a prescribed path, say a stretched string, or along an unguided path through a continuous medium, it is passed along from one element of the path to the next by the interaction between these neighboring elements. One element acts and the other reacts, and nothing is plainer than the simple dynamical relation that the greater the conservative reactions of the elements, that is their inertia and elastic reactions, in comparison with their dissipative reactions, the smaller will be the energy loss during the transmission. A clear grasp of these elementary physical principles makes it obvious that Maxwell's theory insists upon increasing as much as practicable the inductance of telegraphic and telephonic transmission lines, because that increases the conservative inertia reaction of each element of the wire and, the other reactions remaining the same, that increase results in a greater conservation of the energy moving from the transmitting to the receiving station. When Heaviside failed to convert the unbelievers among the telegraph and telephone engineers of former years to this simple doctrine, he proved conclusively that, as an apostle of his great master, Maxwell, his missionary work among the unbelievers had failed to reach their understanding. Many of them even thought that the high inductance doctrine was invented by Heaviside himself, and that it had no direct connection with either Maxwell or his great predecessors. The high inductance propaganda lost thereby the propelling power of these great names. Even today a distinguished telephone engineer says this in the new volumes of the Encyclopedia Brittanica:

"Toward the end of the nineteenth century Oliver Heaviside had proved mathematically that uniformly distributed inductance in a telephone line would diminish both attenuation and distortion, and that if the inductance were great enough . . . the circuit would be distortionless."

The mathematical proof, mentioned here, was not needed by him who understood Maxwell, but, alas! Maxwell's great essay, even after Hertz had thrown the searchlight of his genius upon it, remained a sealed letter to many telephone engineers; hence, their erroneous estimate even today of Heaviside's relation to Maxwell's theory of transmission of magnetic action. The very language employed in the above quotation shows a lack of clear understanding. The writer says, "if the inductance were great enough;" if he had added the words "in comparison with the resistance" he would have made an intelligible statement. He would have also made a valuable contribution to the history of telephony if he had stated that Heaviside's mathematical proof never enabled anybody to find a way of making "the inductance high enough."

During the first score of years following Maxwell's publication of his epoch-making essay the field of telegraphy and telephony offered the best opportunity for interpreting one important aspect of this theory. The opportunity was wasted through lack of understanding in spite of Heaviside's and Vaschy's noble missionary efforts among the telegraph and telephone engineers, and the advancement of the telegraph and telephone art was retarded. What is the real obstacle which prevented the creation of a harmonious cooperation between theory and practise?

(To be continued)

DISCUSSION ON EXPERIMENTAL DETERMINATION OF LOSSES FROM ALTERNATORS[1]

(CONTINUED FROM PAGE 1157 NOVEMBER JOURNAL)

E. Roth: Very interesting remarks have been made by Messrs W. F. Dawson, B. L. Barns, P. A. Borden, and C. J. Fechheimer concerning the application of the method which H. M. Hobart demonstrated in 1913[2] for the determination of the losses in totally enclosed and ventilated electric machines, by the calibration of the air circuit which permits elimination of the measurement of rate in flow of the cooling air. These remarks have shown the high merit of the various alternatives of this method, which ought to be generalized owing to its great usefulness in industrial practise. For this reason, two alternatives, of which one corresponds to that referred to by Mr. Dawson and the other to the one I have developed in the paper mentioned by Mr. Barns, have been submitted by the French National Committee to the International Electrotechnical Commission to be introduced in the rules concerning the tests of electrical machines. It may be of interest to quote this text which is being brought to the knowledge of American engineers:

"*Methods of Measuring the Losses in Totally Enclosed Machines Cooled by a Circulating Fluid.* In machines cooled by a circulating fluid, the greater part of the losses can be deduced from the measurement of the amount of heat carried away by the fluid. In the two methods hereinafter described this amount of heat can be measured by a preliminary calibration of the ventilation circuit. In this method, the rate of flow of the fluid appears in the correcting factors only.

The total losses of the machines are made up of those carried away by the fluid, augmented by the losses transmitted to the ground by conduction, the losses radiated from the surface of the machine in contact with the ambient air, the friction losses in the bearings and, whenever a gaseous fluid is used, the power corresponding to the increase of the kinetic energy of the gas.

The conduction loss to the ground, which cannot be measured, is negligible; the losses, P_r, radiated from the surface, can be estimated assuming that the power emitted per square meter of the frame surface in contact with the ambient air is 10 watts for a difference of one deg. cent. between the temperature of the frame surface and that of the air.

To determine the portion P_f of the friction losses in the bearings that the fluid does not carry away, or the total friction losses in the bearings when these are separate from the end-shields, proper means are indicated in each case.

The power P_c transformed into kinetic energy when a gaseous fluid is used is, in general, negligible.

a. A test is made at any rating and the temperature rise of the fluid Δt_1 is measured; then the running conditions being the same, a given power P_0 is consumed in a heating resistance placed in the path of the air and the new temperature rise of the air Δt_2 is measured.

If, in the running conditions for which it is proposed to determine the losses, the temperature rise of the fluid is Δt (the resistance being out of circuit), the losses carried away by the fluid are

$$P = P_0 \frac{\Delta t}{\Delta t_2 - \Delta t_1}$$

To build up the total losses, the value of P is to be augmented by the power P_r radiated from the surface, the losses P_f, and further, in the event of a gas, the losses P_c, corresponding to the increase of kinetic energy of the gas.

The losses P_f are determined as follows: With the machine being run as a motor at no-load, the power input P'' is measured including the power required for the excitation; besides, the losses P', carried away by the fluid, and determined from the measurement of the temperature rise $\Delta t'$ of the air, are

$$P' = P_0 \frac{\Delta t'}{\Delta t_2 - \Delta t_1}$$

The losses P_f are then

$$P_f = P'' - P' - P_r$$

In fact when a gaseous fluid is used the losses P_f still include the losses P_c corresponding to the increase of the kinetic energy of the gas.

When the rate of the flow of the fluid is different in the test at the contemplated rating from that in the calibration test, then some corrections should be introduced.

When water is employed, the rate of flow is checked in both cases.

In the case of a gaseous fluid, it is essential to multiply each temperature rise Δt by a correcting factor $\frac{p\,v}{T}$ proportional to the corresponding mass rate of flow, p being the absolute pressure, T the absolute temperature and v the speed, measured in relative values at the same point in the three tests, at the exhaust for example.

The correcting factor $\frac{p\,v}{T}$ may be expressed by means of usual quantities. In the case of air, if at a given rating and at a given point the temperature is t, the speed v, and the static pressure above the barometric pressure h expressed in mm. of water, b being the barometric pressure expressed in mm. of mercury during the test, then the correcting factor is:

$$\frac{v\,(13.6\,b + h)}{273 + t}$$

b. The machine is run idle as a motor at two different voltages, one U_1 as low, the other U_2 as high as possible[3], the power inputs being measured as well as the corresponding temperature rises. From the powers measured the power radiated is to be subtracted, and in the case of separately excited machines the excitation power is to be added. When the excitation is supplied by a direct-driven exciter, the losses in the exciter should be subtracted. Thus two values of input, P_1 and P_2, corresponding to temperature rises Δt_1 and Δt_2, are obtained. The temperature rise of the air for a difference of powers, $P_2 - P_1$ would be $\Delta t_2 - \Delta t_1$; therefore if at the contemplated rating the temperature rise of the fluid is Δt, then the losses carried away by the fluid are, at the same rating,

$$P = (P_2 - P_1) \frac{\Delta t}{\Delta t_2 - \Delta t_1}$$

To obtain the total losses, it is necessary to increase P by the power P_r radiated from the surface, the portion P_f of the friction losses in the bearings not carried away by the fluid, and further, in the event of a gaseous fluid, the losses P_c corresponding to the increase of the kinetic energy of the gas.

The sum of the losses P_f and P_c is

$$\frac{P_1\,\Delta t_2 - P_2\,\Delta t_1}{\Delta t_2 - \Delta t_1}$$

As in the former case, a correction should be introduced to account for a casual variation of the rate of flow of the fluid. In the case of air, each of the temperature rises is to be affected by a corresponding correcting factor:

$$\frac{v\,(13.6\,b + h)}{273 + t}$$

1. A. I. E. E. JOURNAL, May, 1926, p. 422.
2. H. M. Hobart, A. I. E. E. TRANS., 1913, p. 645.
3. In the case of an alternator, the excitation is adjusted to a power factor equal to unity.

When making the calibration measurement, it is advantageous, in order to increase the precision, to disconnect the machine under test from the driving engine (steam turbine, gas engine) or from the driven machine (compressor, etc. . .).”

Mr. Fechheimer remarks rightly that the tests have been carried out on an insufficient number of machines; this is why I have appealed to other manufacturers to have this series of tests completed. I have had the occasion to report other tests at the New York meeting of the International Electrotechnical Commission the results of which are included in the following able:

to the coefficient k, this is, in fact, not constant in turboalternators with entirely magnetic bands; in this case, as pointed out by Mr. Freiburghouse, the temperature rise in the end structure of the stator is much higher when the machine is under-excited than when it is over-excited, which means that the losses due to the current are not constant. It is easy to give the reasons for this phenomenon. The method I propose is therefore to be employed with caution in turbo alternators with magnetic bands, but it is applicable in the case of non-magnetic bands.

I am in full agreement with Mr. Fechheimer's statement

TABLE I

RESULTS OF TESTS ON THE LOSSES OF ALTERNATORS UNDER LOAD

Alternator No.	1	2	3	4		5	6
Capacity in kv-a	320	125	7500	150		1470	1250
Number of poles	26	8	8	8		2	2
Type of alternator	Salient poles	Salient poles	Salient poles	Salient poles		Cylindrical core	Cylindrical core
Particulars						Non-magnetic band	Magnetic band
Losses in the teeth in per cent of the total iron losses at no-load (from calculation)	51	32	33	30		11	10
Losses in the core in similar conditions	49	68	67	70		89	90
Inductive drop of leakage in the armature, in per cent of the normal voltage with the normal current	27	7	17	7		11	8
Inductive drop in per cent of the total inductive drop of leakage: in the iron	47	55	52	52		10	13
Inductive drop in per cent of the total inductive drop of leakage: in the coil ends	53	45	48	48		90	87
				Three-phase	Single-phase		
$\frac{k_{sc}}{k}$	1.04	1.01	1.11	0.97	1	1	1.2
$\frac{x_p}{x}$	1.02	1.02	0.51	1.02	1.35	0.73	1.48

k = ratio of the electric losses on load to the $I^2 R$ losses with same armature current.
k_{sc} = ratio of the electric short-circuit losses to the $I^2 R$ losses with same armature current.
x_p = inductive drop of loss.
x = inductive drop of leakage.

This table contains the constants which might influence the ratio $\frac{x_p}{x}$, which are the distribution of the losses in the teeth and in the core, as well as the ratio of the inductive drop due to the coil ends to that in the teeth. It can be seen that some of the results of these comparisons are in contradiction and that the number of tests is insufficient to permit definite conclusions to be drawn in this regard.

It appears, however, that a conclusion can be derived from these tests; that is, that the short-circuit losses seem to represent the exact value of the electric losses on load. With the exception of machine No. 6, the ratio $\frac{k_{sc}}{k}$ is in fact approximately equal to unity, which corresponds to the result found by Mr. Dawson, which has been confirmed by Mr. W. J. Foster. This result justifies the introduction in the American rules, and in those of other national committees, of the determination of the additional losses by the method of short-circuit losses, and this method ought to be adopted also by the International Electrotechnical Commission.

With regard to turbo alternators, Mr. Foster rightly remarks that the short-circuit losses in these machines may be much higher than the actual electric losses; but this is true only when the retaining band is of a magnetic material; in the case of non-magnetic bands, however, the short-circuit test gives the actual value of the losses as shown by the test No. 5.

As for the question raised by Mr. Freiburghouse in regard

that the no-load-loss curve is not a quadratic parabola when the machine is saturated, but in my paper I have referred to the quadratic parabola solely as a special case of the more general case, which is treated by formulas (**2**) to (**6**), where no assumption whatever is made with regard to the form of the no-load curve $f(U)$.

In conclusion, I should like to add the results of several tests we have carried out at the Société Alsacienne, at Belfort, on the subject of the no-load losses in a machine when the shape of the field curve at the surface of the pole differs appreciably from a sine wave. These tests were carried out in order to find out whether one was allowed, as generally admitted, to consider the iron losses under short circuit as negligible.

The field curve under short-circuit conditions is, in fact, much distorted and the iron losses might possibly be very high, particularly in the case of alternators with very high armature reaction and very large leakage.

These tests have been conducted as follows:

One coil was placed on the rotor of a small induction motor to embrace one pole pitch, the ends of which coil were connected through collecting rings to an oscillograph or a voltmeter. This rotor constituted the armature of a small alternator of which the field was the stator. By varying the connection of the windings of the three phases it has been possible to obtain several curves of the field, four of which are represented in Fig. 1 herewith. Curve I is nearly a sine wave; Curve II is trapezoidal; Curve III has nearly the same shape as the field curve under short-circuit of the alternator and Curve IV is similar in shape to the field curve in the case of a salient-pole alternator.

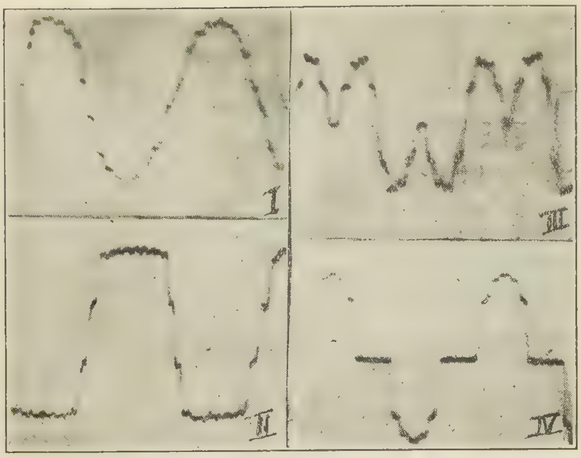

Fig. 1

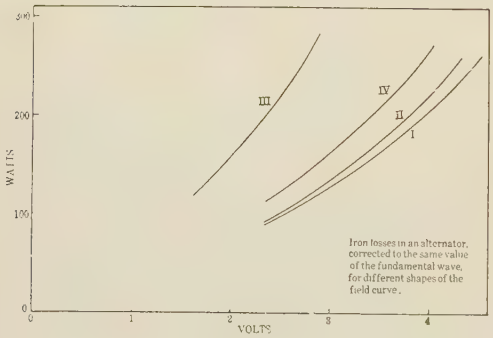

Fig. 2

The power was measured by a torsion dynamometer, the readings being obtained by an optical system of high precision.

The results of these curves are represented in relative values by the curves in Fig. 2. For a same fundamental wave the losses corresponding to the Curves I, II, IV and III are in the ratio:

1 : 1.04 : 1.27 : 2.27

The amplitudes of the 3rd, 5th and 7th harmonics, in percentage of the fundamental, are, for Curves II, IV and III, as follows:

	3rd	5th	7th
II	19.1	4.2	2.5
IV	30.5	14.3	3.0
III	67.2	3.3	12.0

With regard to the losses, the curves range according to the value of the 3rd harmonic.

We have said that the losses due to Curve III, for equal value of the fundamental wave, are 2.27 times as large as for the sine wave. Roughly, for an alternator with 18 per cent leakage, the following calculation could then be made: Admitting that Curve III really represents the field curve under short circuit of the alternator considered, and that the losses vary as the square of the density of flux, the iron losses will be $0.18^2 \times 2.27$; that is, 7.4 per cent of the iron losses with normal flux. The losses, therefore, are not entirely negligible in this kind of machine especially as the 3rd harmonic is actually much more pronounced than in Curve III as obtained in the tests.

Discussion at Annual Convention

SOME GRAPHICAL SOLUTIONS OF A-C. CIRCUITS[1]

(Lee)

White Sulphur Springs, W. Va., June 23, 1926

M. I. Pupin: This paper recalled to my mind the first paper which I read relating to an a-c. circuit in which a simple harmonic force is impressed and the resulting current is complex harmonic. It was a paper written by the late Professor Rowland of Johns Hopkins, about thirty-eight years ago.

He pointed out—and I think he was among the first to do so—that in a circuit in which one of the reactions is not simple harmonic, you may get a current which is complex harmonic although the impressed e. m. f. is simple harmonic. He considered the case of an induction coil with an iron core going through a cycle of magnetization and de-magnetization. Since the magnetic property of that core goes through a complete cycle in which the core does not act the same at any two consecutive stages on account of the variable permeability, you have a reaction due to an inductance which varies periodically. All you can say about that reaction is that it is a harmonic function having a fundamental period—equal to that of the impressed motive force. By Fourier's theory, you can expand that function in an infinite series of harmonics which are odd multiples of the fundamental.

We have a great many cases like that in electrical engineering—cases of circuits in which one of the electromagnetic constants is a harmonic function of the time. For instance, in an induction motor the mutual inductance between armature and field is a periodic function of the time which is determined by the speed of the motor. You cannot treat this case in the same way in which you treat ordinary a-c. circuits, although many engineers do when they employ the graphical method.

I do not use the graphical method in that way and I explain to my students—graduate students to be sure—why I don't use it,—because it is misleading and does not give the real physics of the reactions of the operation of the induction motor. That is true of the single-phase induction motor, and to a great extent of the polyphase induction motor. You can't treat these circuits the same as you treat circuits in which all of the electromagnetic constants remain invariable. You can, by the use of a graphical method, get approximately good results, but you don't get exact results. Exact results demand going back to Maxwell and a treatment of the circuits in the Maxwellian fashion. To be sure, that is not the way to avoid complicated mathematics. But it may be complicated for some people and not complicated for a student who has been tolerably well trained in mathematical operations, and we have quite a number of them.

In our discussion of electrical circuits we deal with differential equations. The equation of reactions is a differential equation and it is the fundamental equation in the theory of electrical circuits. It is a linear differential equation with constant coefficients as long as resistance, inductance and capacity are constant. I think a sophomore can handle such an equation.

Some of us have an idea that all equations expressing the law of actions and reactions in electrical circuits are differential equations with constant coefficients. That is not the case. Very often in some very important problems, as in induction motors, the law of equality of actions and reactions does not lead to differential equations with constant coefficients. They are linear but with variable coefficients and demand a different treatment. You cannot treat them by the graphical method,

1. A. I. E. E. Journal, November, 1926, p. 1078.

with all due respect to the excellency of the graphical method in some cases.

You can't apply it in all cases, as you know, of course, and the only object of my talk is to call your attention to that as forcibly as I can in order to avoid giving the student the impression that he can treat all a-c. problems by the graphical method. It cannot be done.

There is one very interesting case I shall mention here, which probably will not be familiar to all of you, and it is this: It is a vacuum-tube oscillator in wireless telegraphy. There is a new piece of apparatus which is just as important as any generator. Why? Because it is the foundation of radio broadcasting, and that is a great thing. That is one of the great achievements of the electrical engineer's profession. The ability to transmit the spoken word from any place in the United States to any other place in the United States, and perhaps to any other place in the world, is a great achievement—a tremendous achievement, and it is made possible by the vacuum-tube oscillator invented by a student of mine, Armstrong, in my laboratory at Columbia.

Another student of mine, of the General Electric Company, came almost as near to it as Armstrong did. I think that is due, to a certain extent, to my talking to them about circuits that cannot be treated by the graphical method. In fact, I lectured about a method of creating a-c. oscillations of different frequencies by means of induction machines. Armstrong was listening intently and when I got through one day he came to me and said, "Professor, your theory is very fine, but I can do the same thing in a much simpler way by using the vacuum tube.—" And he did. I decided that he was right and my mathematics and machine could go into the scrap heap.

I think that particular case justifies me in wanting you to impress upon the students and your friends that there are a-c. circuits which cannot be treated by the graphical method.

W. P. Dobson: Mr. Lee has described methods admitting of a wide variety of application, a feature which most graphical methods do not possess.

In La Cour and Bragstad's "Theory and Calculation of Electric Currents," Chapter III, methods similar to those of Mr. Lee, are described. Impedance and admittance are represented by vectors and the operations $I.\ Z$ and $Y.\ E$ are carried out graphically in essentially the same manner as indicated in Figs. 1 to 5 of Mr. Lee's paper. Thus the voltage curve at the terminals of a constant impedance is similar to the current curve but corresponding vectors are displaced by the angle $\varphi = \tan^{-1} \frac{n}{r}$ and the lengths are in the ratio $Z : 1$. If new axes be chosen rotated in the negative direction through an angle φ and if suitable scales for current and voltage be chosen then the current curve will be the voltage curve referred to the new axes. In the case of a circuit having variable impedance La Cour and Bragstad make use of the geometrical principle of inversion. Thus the admittance curve is the inverse of the image in the axis of reals of the impedance curve. In Mr. Lee's first example, Fig. 14, the circle $o\ a'$ is the inverse of the image of $a\ B$. This is the admittance curve. It will also be the current curve (to a suitable scale) referred to a new set of axes displaced 30 deg. in the negative direction. The same curve may also represent the voltage on the load $E - I\ Z$. Referring to Fig. 15 it may be shown that if c^1 is taken as the origin and $c^1\ o$ the axis of reals, the curve $c^1\ o$ will represent, to a certain scale, the voltage on the load. This renders the construction in Fig. 16 unnecessary. The utility of La Cour's method lies in the fact that only one diagram is necessary. There are two sets of axes, one for voltage and the other for current.

The application of graphical methods to the calculation of electric circuits is often unsatisfactory unless power can be represented on the diagram. La Cour and Bragstad obtain constructions for both power and efficiency.

The chief advantage of graphical methods in most cases lies in the power of visualization which they supply. For numerical work they seldom offer any advantage over arithmetical methods. They frequently do not yield sufficiently accurate results and their application is limited by the quantities which we desire to investigate. An excellent example of the utility of graphical methods is Mr. C. H. Holladay's chart for transmission lines,[2] in which voltage, currents and power are represented on the same diagram.

C. A. Adams: I have been tremendously interested in what Dr. Pupin has said and agree that in our engineering teaching we are apt to slur over the more exact methods of analysis in favor of approximate methods. I think it is safe to say that nearly all methods of solving engineering problems as presented to students of engineering are approximate methods and in most cases very crudely approximate. Moreover, the student, in ninety-five cases out of a hundred, doesn't know that the solution is approximate or what the approximations are. The solution is good for a narrow range within the desirable practical degree of accuracy. When he gets outside of that range, he is lost. That this is so has been proved time and time again by the failure of the better engineers to solve satisfactorily fairly simple problems presented to them. So I am in hearty sympathy with the spirit of Dr. Pupin's remarks.

I wonder, however, if in the case of the induction motor and other pieces of electrical machinery it is humanly possible to be at all exact in our analysis? You may try to take account of the variability of some of the factors we ordinarily assume constant. They vary in some cases in a manner which can be expressed only by a long series of terms, and even then only approximately. The properties of the materials are never known accurately. No mathematical analysis, however complicated can predetermine with accuracy the core losses or the magnetic-circuit relations in a piece of rotating electrical machinery. It is merely a question of degree, and a question of judgment as to whether a more extended mathematical analysis is warranted by the resulting gain in accuracy.

The mistake we make in engineering education is in failing to emphasize the approximations, in failing to provide the student with a scientific foundation on which he can build his own solutions and make his own approximations with his eyes open and with full knowledge of the errors involved and the range of practise within which these errors are of negligible importance. Then when he gets into some other range of experience he will be able to carry his refinements farther, or make different approximations.

Of the approximate methods of analysis and visualization, some are tremendously valuable; as, for example, the circle loci of Mr. Lee's paper. In this connection I refer Mr. Lee to a series of articles I wrote for the *Harvard Engineering Journal* in 1905-1906, in which I discussed the circular loci of induction motors and incidentally used almost identically the same method as that employed by Mr. Lee. These loci are very useful in providing a simple method of visualizing the approximate relations between the constants of the motor and its operating characteristics.

As long as the student or engineer, in making his applications, knows where the approximations have been made, the magnitude of the resulting errors and how accurate it is necessary to be in his solution, he can use mathematics or graphical methods intelligently.

That is really the important point at issue, and the mistake which we have made in the past is exactly that pointed out so clearly by Dr. Pupin. We carry our students through a lot of superficial approximation methods of solving problems without sufficient emphasis on the approximations without giving them the ability to go more deeply into the analysis. In fact, in many cases they have a notion that they are getting a deep, theoretical treatment of the subject. Most of them think it is

2. TRANS. A. I. E. E., 1922, p. 785.

too theoretical, when as a matter of fact the old complaint of the employers in industry that our men were too theoretical was all nonsense. The only difficulty was that really they were not theoretical enough, because had they been more so they would have obtained good practical results.

D. C. Prince: We have had two general points of view presented as to methods of solving problems. One is that we take our problem and divide it up into the form of an infinite series. The other is that we take the outstanding phases of it and produce a graphical solution for them.

The principal advantage of the graphical method is that it gives a general picture which you are very likely not to get by infinite series. The advantage of the infinite series is accuracy, but at the same time you set up your equations and get out certain results which are all right provided your series is truly convergent and has been properly taken.

For instance, Doctor Pupin has raised the question of applying a series to the vacuum tube. I have seen a great many of those analyses, and as long as the current does not stop, it is possible to make a very nice convergent series which will cover the case. If you press the output and go in the direction of a highly efficient oscillating circuit where the current is in the form of jabs occupying only a few degrees of arc, you find you have repeated points of discontinuity appearing, which present points of difficulty. If the current is zero for a considerable time, we then have in our series a large number of different waves, all of which add to zero and therefore all of which are not there for a considerable part of the time.

Therefore there are problems which seem to demand coming back to a more or less laborious first principle in which you work the thing out. In a paper in the *Journal* of the Radio Institute[3] we presented such an idea of going after in a more or less graphical way the method of working out the oscillator because the series methods, if sufficiently developed to be exact, seemed to lead off to a point where you could not tell which terms were valuable and which were not.

M. I. Pupin: Somebody couldn't tell, but others could. Armstrong could.

D. C. Prince: Yes, but he is working almost altogether with cases where he does not press efficiency to a point that strikes discontinuity.

M. I. Pupin: Discontinuities such as a man can make with his voice are discontinuities which happen after the stationary state has been reached and you don't care about them. You are dealing then with the stationary state. The hand of man is slow and his voice is slow and these oscillations go perhaps a million times per second. You are dealing with a stationary state there anyway.

D. C. Prince: I referred particularly to discontinuities that occur at the frequency of the oscillation.

M. I. Pupin: But there are no discontinuities of that kind, so far as I know.

D. C. Prince: In the ordinary amplifier you always have to provide for proportional current so you may get some sort of current variation which will be a continuous procedure with harmonics of various sorts. As soon as you begin to chop the waves down to zero so the current actually flows for a small part of a cycle, then you have discontinuity repeating as fast as the cyclic variation. These intervals of zero current last as long as three-quarters of a cycle or more. In oscillating circuits, if you make an analysis of the possible circuit efficiency, it approaches 50 per cent on the basis that the waves shall come down and be tangent to the axis. We get efficiencies of 80 per cent and more.

M. I. Pupin: Those are periods that are equal periods and follow others of equal intervals of time. That gives you simply another series which is a continuous series.

D. C. Prince: You can produce a continuous series, but what it means is that you are making out of a blank a continuous series of waves which are not there at all.

M. I. Pupin: That doesn't make any difference.

Harold Pender: Not long ago I was talking to the representative of one of the leading publishers of technical books in this country. I asked him why he didn't publish some really good textbooks on electrical engineering. His reply was that his best books on electrical engineering subjects did not sell. This is typical of the present tendency in engineering teaching. Apparently what is desired by a great many teachers is a type of book which will make the teaching of electrical engineering easy; a book that will require a minimum amount of thought on the part of the student and a minimum amount of effort on the part of the instructor. That is one of the reasons why graphical methods are so much in vogue. The teacher seems to wish to find a means of getting over the difficult fundamental part and to give the student something with which he can play; some nice little vectors with which he can juggle as he would with toys.

Over and over again in teaching the elements of alternating currents I have seen that the students find great difficulty in understanding the basic theory based on the instantaneous values. But just so soon as they think they understand the vector representation of alternating currents, everything, (to their mind at any rate) becomes extremely simple and easy. I think if we can get the student to think of things as actually happening and not to think of alternating currents, for example, as so many vectors, which he must draw on a sheet of paper and by some juggling get an answer, the more thoroughly will the student understand what it is all about.

There is a book which appeared about twenty years ago, by Professor Bedell on Alternating Currents. I think it is used still at one university, although I am not sure of that. I know it was in use a few years ago. Most people think that that book is very old-fashioned. I would suggest that some of the men who are teachers get a copy of the book and read it. The author of the book is a man who grew up on instantaneous values. He knows his subject and he is not inclined to avoid difficulties by using vectors and graphical solutions.

R. E. Doherty: I should dislike to have the idea firmly entrenched in the minds of people here that graphical methods are in general of no very great use. I agree completely with Dr. Pupin, Mr. Adams and Dr. Pender in what they have said with respect to graphical solutions, and with their idea of what should be given out in general to students; nevertheless, I wish to say, that I have found graphical solutions of problems to be of great help. I understand that Dr. Pupin refers specifically to quantities which vary as sine waves; that is, sinusoids.

M. I. Pupin: To circuits which contain variable elements—variable reactions.

R. E. Doherty: Differential equations, of course, which cannot be solved by any functions familiar to us can sometimes be found very conveniently by carrying out graphical construction.

F. W. Lee: Dr. Pupin's points are well taken because ordinary circuit analysis does not consider the variation of resistance with the frequency and the current density in a conductor, also it neglects the variation of energy dissipation and change of induction with variable magnetic intensities, nor will it account for changes of capacity and power factor as well as previous cyclic conditions of condenser systems. It has been the custom to combine these phenomena into effective resistances and reactances; taken sufficiently large to insure safety. At best the linear differential equation with constant coefficients is an approximation.

I am sure that the electrical profession would be delighted to have a new system of mathematics which takes cognizance of all these facts and which would be able to give quick accurate solutions. It should not be forgotten, however, that although the solution of the linear differential equation with constant

3. June, August and October, 1923.

coefficients as presented by Rowland, was available before Dr. A. E. Kennelly first introduced the complex vector in 1893 in a paper on "Impedance;"[4] this, followed by the application of the complex vector to Kirchhoff's law and electrical machinery by Dr. Steinmetz, did more to clarify and simplify the understanding of a-c. phenomena than any other single factor. Most engineers are very loath to abandon the electrical analysis founded upon these conceptions unless something simple and better is offered as a substitute.

Also I do not wish to detract from the classical work of Dr. Arnold upon graphical presentations of a-c. circuits. Sufficient amount of fundamental material was introduced in order to give ample background to a clear understanding of the complete contents of the paper.

POWER TRANSMISSION AND DISTRIBUTION

(Thomas)

White Sulphur Springs, W. Va., June 24, 1926

W. S. Lee: Referring to interconnection in the Southern States, this interconnection has been in effect something like 15 to 18 years. I am afraid that this committee is going to get on dangerous grounds when they try to have the entire area controlled by devices from one point.

You should consider that the Southern Systems are interconnected for over 1000 mi. and there are six or seven different companies operating in a somewhat local territory. From the Georgia line to the Virginia line the Southern Power Company system covers something over 400 mi. It is necessary to have it cut up into divisions. The head dispatcher rules certain base or main lines and each local dispatcher controls a certain territory operating around him. Any impression that this paper might give of trying to get one operator to manipulate all the interconnecting companies, I think would be wrong. That is a nice theory, but I think it is hardly practical.

In North Carolina we have an interconnection with the Georgia Railway on the West, the Carolina Power on the East, and in case of any trouble or interruption, the dispatchers pick up a load without referring the matter to an executive.

It can readily be seen that the point on cooperation referred to is pretty well carried out by the group of Southern companies.

The power plants, or undeveloped sites today, are very large as a usual thing, the smaller ones, the ones that are easily developed have been developed. Often times on account of lack of load or financial arrangement, there is a tendency to develop a plant for a small amount of money. Sometimes it is not a complete development of the project.

I suggest that the committee consider the possibility of steam generation by electricity. I am quite mindful of the fact that we cannot produce steam by electricity at a profitable price, but if we have these large projects that should be completely developed economically, then why not use steam generation to help carry the system along during the earlier stages?

The usual method of developing a water power is to find, as you know, three things; site, money and load.

Now it is a very common practise to go out and make long-term contracts at low rates with the idea of inducing capital. If these big projects can be developed by taking part load as a steam load at a very low price it is just putting an implement of earning into that system that may be useful. As other customers develop, take off steam production and sell for regular commercial service.

Another company with which I am connected has just completed a plant of 540,000-h. p. installation. The plant was financed in a very unusual way. One customer made a 40,000-h. p. contract for primary power and a 160,000-h. p. contract for making steam. That steam contract was cancelable in twelve months.

4. A. I. E. E. Trans., 1893, p. 116.

That contract was canceled before it went into operation and notice was given of the cancelation, but it did furnish a certain implement of revenue that made possible the carrying out of the project in a big economical and fully developed way.

The manufacturers are not much interested in making steam apparatus. It is very simple but they should encourage it with the idea of what it will make possible in other developments.

W. A. Del Mar: I should like to discuss the following statement in this report: "It has been learned that one of the principal causes of the failures in high-voltage cable was the use of impregnating compounds that were unstable under the dielectric stresses and temperatures of normal operation."

I think the committee was going ahead of their exact knowledge in making that statement. I think that it is more than doubtful whether failures in high-voltage cables are caused by the instability of impregnating compounds.

As I pointed out in a recent paper[1] it is far more likely that the decomposition of the compound and the failure of the cable are both results of conditions, such as low hydrostatic pressure in the cable, which promote ionization.

It is also well known that 25,000-volt cables in which the oil has been considerably decomposed and so far as the eye could judge, in some cases entirely converted into X, have continued in operation for years.

Another somewhat optimistic statement is that some of the manufacturers and the Electrical Testing Laboratories have developed tests which will aid the selection of compounds, from the point of view of stability. I believe there is some hope that such tests may be developed, but at the present time, the ones which have been tried have been very unsatisfactory and uncertain results have been obtained. It is impossible for one laboratory to check another one and the discrepancy in this regard is very marked.

Another strange fact illustrating our general ignorance of the subject is that some 25,000-volt cables made with highly unstable oil, as determined by the above tests, have not developed X after three or four years' operation, whereas others made with comparatively stable oil, very much more stable, indeed, have developed X after a few months of operation.

I share the opinion of our European friends that American cable operators study the specification and manufacture of cables too much and their operation too little, and that American cable manufacturers have been equally delinquent in their interest in the installation and jointing of cables.

R. D. Evans: The subject of special characteristics of machines and their effect upon stability is pretty well understood. The special characteristics may be utilized in two ways, either to increase the margin of stability or to increase the amount of power that may be transmitted with the same margin of stability.

Recent studies have indicated that under some conditions it is possible to obtain both advantages with a lower total investment cost. I wish to make the point clear that these studies indicated it is possible to use machines of more expensive construction and yet obtain a system including machinery at a lower total cost.

As the result of such studies, some of the recent hydroelectric undertakings have involved decisions to use machines with special characteristics. I mention this point because it seems to me that it may be indicative of a trend, or new practise in regard to application of such machines.

Many years ago machines of normal reactance were employed, and in order to improve regulation, machines with better inherent characteristics were used. Then the advent of the automatic voltage regulator made it possible to obtain good regulation with machines of more nearly normal design proportions.

Now it appears from the two contracts that there may be a trend returning to the use of low-reactance machines for the special applications of high-power and long-distance transmission.

1. *The Effect af Internal Vacua upon the Operation of High-Voltage Cables* A. I. E. E. Journal, July 1926, p. 627.

Such a trend may also include quick-response excitation systems.

One of the subjects suggested in the Committee Report as suitable for discussion is concerned with collection and analysis of data relating to stability. In this connection it may be pointed out that the angle-outage curve is a very useful index for comparing in a general way the relative stability characteristics of power systems.

H. R. Summerhayes: I think this subject of stability is perhaps wrongly named. It should be named "power limitations." With that name it would be more readily understood.

I have a little hobby on this subject to improve the limit of power that can be transmitted over a line, and that is what I call a "compensated line."

To balance the reactance of each section of line we employ a unit of series capacity, and the voltage drop over the reactance is neutralized by the voltage drop over the capacity for each section and then you have the compensated line in which all that remains is the resistance of the line. As compared with a line having reactance only, and the same generating and receiving apparatus, the amount of power transmitted will be greatly increased.

Of course, there are certain practical difficulties in the use of these series condensers which I hope will be solved. I think they will because the advantage of using the series condenser is so great that there is bound to be a good deal of study devoted to eliminating the practical difficulties in their use.

Another objection is the expense. In time that may come down, so that I am just bringing this in as a prediction that some day, with these very large lines of very large power, shall see the use of series condensers with the power going through the condensers.

It is the sort of thing that doesn't present any great advantage in small powers and therefore it is difficult to make a commercial experiment because we like to start with the small powers in making experiments, and as there is no great advantage in the smaller units we have to make our experiments on large power scales. Personally I think we shall have to develop it in the laboratory first and then supply it on a large scale. That of course, requires a good deal of courage.

Another point which I want to mention is the standardization of voltages for transmission. The Public Policy Committee of the N. E. L. A. this year adopted a resolution in which they urged as a matter of policy the further interconnection of systems and that the managers or executives of neighboring systems study the advantages and the methods of interconnection. In that resolution they also advocated the standardization of voltages above 60,000.

That may come as a surprise to a good many people, because I think many of us have thought that we had standard voltages above 60,000, but apparently that is not the case. It is a very large issue with the N. E. L. A. just now, and I understand that it is to be taken up by the Institute as well; just what voltages should be standardized and what should be the zones of standard voltages.

This is a very important subject and I believe it should be given careful consideration as it is of great economic importance.

In the report of the Committee on Transmission and Distribution, there was recommended a careful study of the value of booster transformers at the point of interconnection between systems. That means voltage-ratio control under load. The ratio may have to be controlled and reversed, perhaps, and you have to be able to make a considerable change in the voltage of the transformer with power going in either direction. There have been important developments in that line and a great many kw. of transformers have been put out and installed with ratio control.

Several systems have been in use and it appears that no one method is adaptable for all voltages and all powers. No doubt experience will show just what method will survive. Probably there will be several methods in use that can be made adaptable to different conditions. At any rate, the subject is of very great importance since it involves the control of wattless current, power factors, etc., and has a most important bearing on interconnection.

The paper mentions the fact that there is a tendency to extend the time and thermal capacity of current-limiting reactors. That used to be 2 sec. but now it is up to 5 sec. and the tendency is to extend the time still further. Putting copper into the reactor and thus extending the thermal capacity is something that you do without really increasing the total cost.

You may pay more for your reactor but you gain that over the losses so that if the load factor is at all good your annual cost may not be increased at all. You get something for nothing there. That tendency is very noticeable.

Another thing that was brought out at the meeting of the N. E. L. A. Apparatus Committee is the new development in starting compensators. Perhaps that should have been noted in the report of the Protective Devices Committee. There is now under way the development of a time-delay under-voltage release attachment to put on hand-starting compensators. All of you are familiar with the shutting down of motors due to momentary line disturbances and there is a lot of trouble that really need not occur. In many cases the under-voltage devices on the starting compensators have been removed altogether with greatly improved continuity of service.

This time-delay attachment itself, I believe, will eliminate a number of shutdowns. The time delay is as short as 1.5 sec., but it will be enough to take care of many of the transient disturbances.

M. I. Pupin: I should like to ask the last speaker whether he has another hobby which is more popular in Schenectady than this hobby. They use it in wireless telegraphy. It is compensation, not by capacity in series, but by inductances in parallel. Inductances are cheaper as a rule than capacities and require much less attention.

That scheme is 29 years old. A friend of mine, Charles S. Bradley, took out a patent on the scheme. I worked out the mathematical theory for him and then he sold the patent to the General Electric Company. The General Electric, so far as I know, has never used that scheme of balancing the line for large power transmissions, but it is using it today at the wireless station on Long Island for balancing a wireless transmission line; one that runs parallel to the ground and credit is being given to Alexanderson and not to Bradley.

H. R. Summerhayes: I don't know that I can answer that very well, but I do know that the use of the shunt inductance has been suggested a number of times and preliminary propositions have been made out on it, but in almost every case synchronous condensers were used instead because of the ease of adjustment and control of the value.

A field control was considered so important as compared with having the number of inductances with switches, (which were expensive), that we used synchronous condensers. I think Mr. Nickle can tell something about that.

C. A. Nickle: If we have a long line with distributed capacity, it may be represented by a reactance with shunt capacity at either end. It is true that this shunt capacity effect can be cancelled by the use of shunt reactors, and this has been tried on small set-ups.

Now if we have a machine of zero reactance at the sending end of this line, distributed capacity is an advantage. However, when we use a machine of finite reactance, distributed capacity becomes a disadvantage. In fact, if this capacity is sufficiently large, the charging current of the line will be sufficient to excite the generator and the generator will require no other excitation.

It is well known that a generator with no excitation furnished by an exciter can put out no power, so that with the finite genera-

tor, there is always a certain sized generator on a certain sized line which can put no power over the line.

Furthermore, a standard generator which we would ordinarily furnish would have so much reactance, and this charging current of this condenser might furnish so much excitation, that the machine, when transmitting full rated power over the line, would run under its proper excitation. In other words, if we could put more current on the field we should be able to get more power if the machine is running below its rating.

When we put this reactor across the line, the excitation can be increased because we have removed the charging current; thereby we can get more power. This reactor however, costs money and there is another means of making this generator take more excitation which doesn't cost anything.

If the machine is running below its maximum rating so far as field heating is concerned, why put on a reactor to raise the field current when we can merely make the air-gap bigger and accomplish the same result? There is no difference whatsoever except that this takes out material and costs nothing and the reactor does cost something.

When the synchronous reactance of a generator is equal to the charging reactance of the line, the parallel reactance is infinite; therefore, the generator will put out no power.

For exactly the same reason a given size of generator, connected to transmission lines, has always a most favorable number of lines for that generator. If I can get so much power over one line and I put another line in parallel, the power may be increased. But on the other hand, we may find that the power is decreased because we are increasing our charging current which is making our generator weaker instead of stronger.

M. I. Pupin: That old scheme which somebody introduced of replacing the parallel line by condensers at either end has done more mischief than many things of which I know. That is wrong and you cannot do it.

C. A. Nickle: This result is true for one point only; I will admit that; but that is the point that we are studying. At the middle of the line the scheme does not give the same conditions.

M. I. Pupin: I think it is well to bring this out in this discussion, although it is somewhat remote from the main object.

This scheme is particularly useful in the case of transmission of power over cables. When it comes to air lines, it is not quite so important, excepting in wireless telegraphy. When you have a long line, you introduce inductance at periodically recurring points. There are two things which must be observed; the first is the wavelength—the electrical wavelength which is to be transmitted. These inductances must be separated by only a small part of a wavelength.

Then in the second place, these coils must be very highly efficient; that is, the reactance must be very large in comparison with the resistance. In fact, so far as my experimental investigations go, and the theory itself, it is practically impossible to use a coil which has an iron core; and that is where Bradley's invention, which was sold to the General Electric Company, fell to the ground. He didn't know that and the Genral Electric didn't know it.

But the General Electric Company found it out in the wireless work on Long Island. This is exactly what they do on Long Island. They use coils connecting the wireless antenna to the ground. There is no other scheme that will do the same thing that this does. It is an admirable scheme.

The laboratory experiment represented a cable between Buffalo and Syracuse and the frequency was 110 cycles. It reduced the charging current down to one-seventh; there was a very large inductance, and it does not affect your terminal generation in any respect whatever.

It will make no difference in this case how many lines you have connecting with your generator; the charging current will be reduced in each compensated line.

Mr. Nickle: So far as building the generator and testing is concerned, that is done exactly as we predicted. We do get an increased maximum power. Furthermore, when the reactance is equal to the charging current we find we get no power. We have tried it on the quarter-wave line.

On a long-distance line there is no doubt but that, where you can put in the proper number of lines, the charging current will put the excitation up.

What I have been talking about was current-compensated lines. When you put in more lines there you defeat your ends. You should forget about conpensation here. If we put in more lines we do increase the charging current and when we increase the charging current in some cases it gets so high that we can't get any power out of it.

R. N. Conwell: I am glad that Mr. Lee raised the question about the one-man control, because, after going over the report again, I find it is subject to misinterpretation.

Interconnections fall generally into about three classes:

The first one which we have considered is the so-called relay interconnection where relatively small amounts of power are interchanged between systems. Usually the lines are small, the capacity small and the interchange for emergency use only.

There is a second class that has become common and that is where the lines are of high voltage and the distances are great. Usually these are used primarily for firm power interchange.

There is a third class that is being considered at the present time. The lines are relatively short, connecting systems closely situated, but generally for high power, something like 200,000 or 300,000 kv-a. The third class will permit the interchange of the full diversities of adjacent systems attaining the advantages of generation reserve and the most economical operation of the plants in the individual systems. You can readily see that in this third class of interconnection, one-man control is almost an essential if all the advantages are to be obtained.

D. W. Roper: At a time when the art and science of the manufacture of high-tension cable with impregnated paper insulation is advancing as rapidly as it has been for the past few years, it seems quite impossible to prepare a statement that says anything with which the engineers of all the manufacturers and operating companies will agree. The statement to which Mr. Del Mar takes some exception appeared to represent the consensus of opinion of the majority of the members of the Committee at the time it was prepared. While Mr. Del Mar and others have since developed several different theories, the statement to which he takes exception is still the opinion of several members of the Committee.

One operating company has high-tension cable made to practically the same specifications and furnished by seven different manufacturers. The two makes of cables which have not failed in service have a compound which will pass the test developed by the Electrical Testing Laboratories, but the compounds taken from those five cables that have failed in service do not pass the test. In the face of this agreement of service records with the test indications, it does not appear expedient to discard the test or to condemn it in the light of present information.

It will probably take considerably more work in the laboratories, together with a careful examination of several years' service records, to determine definitely the value of any particular theory and the relative importance of the several steps in the process of drying, evacuating and impregnating the paper insulation.

If the selection of the proper compound is such a simple matter and of so little imp tance, it seems difficult to understand why some manufacturers are changing their impregnating compound so frequently.

THE MECHANISM OF BREAKDOWN OF DIELECTRICS[1]

(Hoover)

White Sulphur Springs, W. Va., June 25, 1926

W. A. Del Mar: Mr. Hoover's main thesis is based on certain experimental curves obtained by K. W. Wagner and showing the relation between volts and amperes in various dielectrics. In a discussion of another paper which took place the same year Mr. Peaslee[2] indicated that these curves could be interpreted in terms of volts and current density. Mr. Hoover makes a third step; namely, that these same curves may be interpreted in terms of potential gradient and current density, and he proceeds to build on that. It is disturbing to me that it took three men to take those three steps. I cannot help wondering how many other things we almost know, yet do not quite know, that will require two or three men to elucidate.

There are, however, two points about this conversion of the Wagner volt-ampere curve into the stress-strain curve which require further study. Wagner found in his experiments that the breakdown voltage is proportional to the thickness of insulation, and this either consciously or unconsciously has been assumed by Mr. Hoover when he converted voltage into voltage gradients. On the other hand a good many experimenters have found that that relation, instead of being always linear, is generally a curve with a tendency to flatten toward the axis of thickness. Hence, there must be some limitation to the extent to which we can convert these volt-ampere characteristics into stress-strain characteristics.

A similar argument applies to the area. As Mr Hoover points out, some experiments by Kennelly and Wiseman indicate that unless certain precautions are taken, the breakdown voltage per unit thickness is not the same for insulation of different areas. Yet in converting Wagner's amperes to amperes per square centimeter, it has necessarily been assumed that changing the square centimeters does not affect the stress or the breakdown voltage. That is another point that has been jumped over.

I do not wish to intimate that these things invalidate Mr. Hoover's results. I think, on the contrary, that it simply means that something has been rather jumped over in his presentation.

As Mr. Hoover said, a great many inventions are shown up by this presentation. The various types of graded cables which depend on the old logarithmic formula are all left "up in the air," so to speak. Those of us who have tried to make cables of these various types know that they do not show the increase in dielectric strength that is expected by their inventors. In fact in my experience neither the inter-sheath type of cable nor the type that is graded with three or four different dielectrics shows any of the expected increase in dielectric strength but in the past we never quite understood the reason. Mr. Hoover has furnished the answer.

There is a weak point that Mr. Hoover has skipped over and that is that all of the experiments by Middleton, Dawes and Davis were made with alternating currents, whereas his own theory is worked out for direct currents, as the Wagner volt-ampere characteristics were obtained by experiments with direct voltages. That simply shows there is a gap which remains to be filled. It may indicate that the characteristic a-c. and d-c. curves are identical. Probably that is the explanation, but it is a point that needs to be bridged properly and not jumped over.

The question of high frequencies being the ultimate cause of failures under many conditions, is one which has been in the mind of a great many people for years, and Mr. Hoover cites the very interesting and seemingly conclusive experiments by Kennelly and Wiseman which favor this theory. Some experiments by Gewecke and Krukowski[3] have, however, thrown a little doubt on these conclusions and the situation needs further elucidation.

There is an interesting statement made by Steinmetz[4] that I think is of some interest in connection with Osborne's theory of needle points, and that may bear on Mr. Hoover's experiments with glass. He said, "A particle of higher specific capacity than the surrounding material will concentrate the line of electric force toward itself, creating points or edges of excessive flux density at the poles of the particle. The insulation would char at these points or edges and the shape of the product of chemical decomposition would tend toward the form of a conducting needle with excessive voltage gradients at its ends, gradually piercing the dielectric until final puncture occurs between the terminals. Thus, in laminated insulation consisting of very many layers, a foreign particle in one of the layers, though originally forming only an insignificant part of the total thickness of the dielectric, may gradually but cumulatively in course of time, pierce and destroy the insulation by its electrostatic cutting edges, the average voltage gradients within the dielectric being still very low compared with the testing dielectric strength of the material."

W. F. Davidson: The relation of the several factors determining the voltage distribution or stress within complex insulation is a point which we have neglected in many of our studies on insulation. The present paper indicates a method for determining the stress-strain distribution in a cable on the basis of information called to our attention by K. W. Wagner.

As Mr. Del Mar has brought out, the normal distributions are based on the assumption of continuous potentials, while we are faced in many of our problems with alternating potentials. In the case of alternating potentials, we have, in addition to the cases mentioned by Mr. Hoover, the influence of electrostatic capacity which is of predominant influence in many cases.

I wish that Dr. Whitehead would tell of some of the work that he has been doing at Johns Hopkins University in connection with the same general research activities that Mr. Hoover has been following. However, it may be worth while to indicate some of the results. Working with small cables made under carefully controlled laboratory conditions, he has been investigating specifically the relation between voltage and the power factor of the charging current in samples which have been impregnated with different quantities of air and more recently with quantities of moisture left in the paper. The results are still qualitative but seem to indicate that the way in which the air is distributed through the dielectric has a great influence on the power factor. If the air is in layers, then the power factor increases rapidly after the voltage reaches a certain critical value; if the air is diffused through the entire body, the influence is small. Moisture seems to have an effect something like that of air in layers, but to date he has been unable to isolate the two effects.

Because of such influencing factors I feel that we can do little more with any theory in connection with cable and similar types of complex insulation than take it as a general guide.

Another point of special interest is the development of the importance of the inter-molecular in closely compacted materials. It has seemed to me that we might go a considerable way toward verifying or disproving the assumption if we take some material which could be studied in several different states. Possible carbon dioxide, which is easily obtained as gas, liquid, or solid, or sulphur, which might be obtained in several crystal forms as well as a liquid, might afford a suitable material for investigation.

R. J. Wiseman: Some think dielectric breakdown is distinctly a heat phenomenon resulting from the energy consumed in the dielectric. I have never had that feeling. I have always felt that the heating is an after effect and not a cause. I think Mr. Hoover is also beginning to bring that idea out.

If we assume, as Mr. Hoover has done, that a dielectric has a

1. A. I. E. E. Journal, September, 1926, p. 824.
2. Trans. A. I. E. E., 1922, p. 620.
3. *Archiv. Elektrotechnik* 1914, Vol. 3, p. 63.
4. Trans. A. I. E. E., Vol. 42, p. 1035.

volt-ampere characteristic as shown in Fig. 1, we are taking a possible shape of volt-ampere curve and may be justified in doing it. That, however, is not a general curve and I believe applies only to the material with which Wagner has experimented. Each insulating material or dielectric will have its own kind of curve. This volt-ampere curve will differ for each dielectric as well as for every possible combination of insulating materials such as occur in rubber compounds and various combinations of oil and paper.

Mr. Hoover's Figs. 2, 3 and 4 are very interesting and afford us a fine chance to study the mechanism of breakdown as he views it as well as from our own points of view. It will be necessary to study Fig. 3 and 4 very carefully in order to appreciate their significance because they tend to tie in the close relationship of curves of breakdown obtained by formulas based entirely on voltage stress and those using voltage and current characteristics. They also bring out that breakdown is fundamentally a density action of ions or current or whatever you wish to call it. Instead of calling it strain, I think we ought to call it current density or ionic density. Strain is more of a mechanical consideration and not so much an electrical one.

Several years ago I did some work on the dielectric strength of cables. At that time I tried to explain why the points did not fall along the theoretical curve. I did not work along the lines that Mr. Hoover followed,—namely, current density,—but studied the variation in the maximum voltage stress at the conductor itself. I developed an empirical formula which is really only a correction of the logarithmic formula that we can develop theoretically. In this empirical formula I assumed that the dielectric stress at the conductor, instead of being a constant, was a variable with the size of the conductor itself. I believe it is quite probable that the same condition will be found if the volt-ampere characteristic of the material is obtained. It would be necessary to make tests with single-conductor cables. You cannot take the dielectric in plain sheet form and bring out the characteristic of material in cables unless you know the relationship between the two methods of testing.

The empirical formula, which I believe helps us to explain the departure from theory, is based on ionization. If we take K as the voltage stress at the conductor and r the radius of the conductor and assuming $K = K_0\left(1 + \frac{a}{\sqrt{r}}\right)$ by computing back to K_0 for various diameters of conductor, we shall obtain very closely a constant which I believe is the true dielectric strength of the material. Since obtaining the above formula I have improved it by dividing K as obtained by the theoretical formula by $\sqrt{R}$ where R is the radius of insulation. The voltage formula now becomes:

$$V = K_0\left(1 + \frac{a}{\sqrt{r}}\right) r \sqrt{R}\ 1\,n\ R/r \text{ volts,}$$

Whether the above is the same thing Mr. Hoover is describing, I do not know. I think a study of both is well worth while and intend to make it later myself as I am particularly interested in the subject.

On Fig. 6 we notice the drooping of curves B' and B''. B'' happens to be a curve I obtained. I should like Mr. Hoover to explain not the drooping so much as the departure from the theoretical law, because B'' was obtained with constant insulation radius R and varying conductor radius r. According to theory, we get a maximum voltage breakdown when $r/R = 0.434$. Curve B'' does reach a maximum and decreases, but all values are above the theoretical, based on a constant value of K. This is also true of curve B' obtained by Messrs. Middleton and Davis. I believe it is all a question of ionization. Had we the volt-ampere characteristic of the material I used, we should very likely get the same curve if we computed breakdown in the manner proposed by Mr. Hoover. I believe it adds emphasis to the fact that we must study each kind of dielectric before we are able to arrive at any conclusions.

Mr. Hoover believes that the shape of the curve for B' and B'' may be due to using extremely small conductors. In my own case the smallest conductor was about 1/16 in. in diameter and gave a ratio r/R about 0.2. I doubt if this is small enough to influence the results by possible mechanical considerations. As I recall it, I was able to get very good samples with small conductors.

Referring to the formula:

$$V = K_0\left(1 + \frac{a}{\sqrt{r}}\right) r \cdot \sqrt{R}\ 1\,n\ R/r,$$

it is true that a is a factor depending on the kind of dielectric. We can go even further and say that it may change from plus to minus. If a is zero, we get a straight line horizontal to the abscissa axis if we plot as ordinates $K/\sqrt{R}$ and $1/\sqrt{r}$ as abscissa. This is the condition of a perfectly pure homogeneous dielectric. As the dielectric departs from purity, the line begins to slope, crossing the ordinates positive at $1/\sqrt{r} = O$ and giving a plus sign to a. As the material departs further from purity or homogeneity, a increases and finally takes on a negative sign. In rubber compounds we get large values of a and they may even go negative due to their distinct non-homogeneity. For oil and paper a may or may not go negative according to the nature of each, as well as the amount of air and moisture left in them.

R. W. Atkinson: Many observers have carefully dissected, layer by layer, cable insulation which previously has been subjected to voltage stresses, and obtained thereby very important first-hand knowledge of the phenomenon of breakdown of cable dielectric. Such dissections of insulation in various stages of incipient breakdown have furnished much information about the "mechanism" which results in final breakdown.

A characteristic type of failure now becoming widely known is that resulting from stresses in a three-conductor cable in the filler spaces; that is, outside of the bounds of the tape insulation of the individual conductors. The stresses at this point, while lower than at the surface of the conductor, are not perpendicular to the layers of insulation and result in relatively low strength and incipient failures at this point before there is serious stress adjacent to the conductor surface. It is much easier to obtain visual evidence of this action than in the case of failure of the laminated or taped-on insulation because the time from the inception of failure to the completion is so much greater that many more samples can be found where the process of failure has started but has not been carried to the point of destruction of the evidence. With this type of failure, the steps which take place are now revealed very clearly. Initially, minute discharges take place circumferentially around the insulation. The energy in these intial discharges is so minute that the destruction caused by them is exceedingly slow. It seems probable that the destruction is not directly a thermal one but rather a chemical one caused by the bombardment of the electrons, or perhaps by ultra-violet light. By a little stretching of the imagination, it can be considered that the bombardment results in local high temperatures, the spots of high temperature being practically molecular in dimensions. (On the other hand, although I believe that initially the temperature is not greatly raised in areas larger than those of substantially molecular dimensions, the evidence is insufficient to prove that the destruction is not caused by high temperature in regions of exceedingly small extent, yet of vastly greater dimensions than the molecular.) Undoubtedly the discharges in these spaces are of a high-frequency character and therefore the destruction occurs much more rapidly than would be the case at commercial frequency. When the local destruction has been carried to the point of making the insulation in that region partly conducting, the local area is extended circumferentially and the discharge

gradually takes place between portions of the insulation spaces where there would be normally a considerable difference in potential. The magnitude of these potential differences has been investigated and reported by myself and oth rs, and it has been shown to be a considerable fraction of the voltage applied to the cable. This process is carried on until it results in the development of an amount of energy which is sufficient and so localized that at the ends of these circumferential conducting paths, there are regions of high temperature that will gradually destroy the insulation. Indeed, we have then developed the "needle-point," which is discussed by Osborne and which produces ultimate failure in the way that he has described.

The evidence shows that in many cases failure in portions of the laminated insulation having only radial stresses normally may be caused in a somewhat similar manner; that is, the initial failure is small in extent and results in a gradual local injury, the magnitude of this injury increasing first in severity and then in the area affected.

I hope that it will be possible for Mr. Hoover to continue and extend his experiments with glass. In some ways this material lends itself exceedingly well to an investigation of this kind, inasmuch as it is possible to obtain a very wide range of ratio of the inner to the outer diameter of the cylindrical insulator and to obtain exceedingly high stresses without necessitating either large actual physical dimensions or high voltages. I hope Mr. Hoover will be able to make measurements with the same type of glass and with different wall thicknesses, at the same time taking measurements of the volt-ampere characteristics of the materials so as to make a direct determination as to whether or not there is a departure of the stress from that obtained by the simple mathematical expression and what is the extent of that departure. Mr. Hoover says that in this experiment the chipping nd c acking near the bore of the thermometer tube is undoubtedly a high-frequency phenomenon. Why may this not be something simpler? For instance, a thermal effect as a result of local heating, or perhaps mechanical failure due to mechanical stresses set up by the high electrical stress? Of course, if the glass has zero thermal coefficient of expansion, such as pyrex glass has, the probability of the failure resulting from thermal effect would be small. It will be of interest, however, to know Mr. Hoover's reasons for attributing this chipping and cracking to high-frequency phenomena as such reasons may be entirely adequate for the conclusion given.

Mr. Hoover brings out in impressive manner the important affect on the stress distribution, of variation with voltage of the effective specific inductive capacity r the resistivity of the insulating material. Undoubtedly, in a number of cases, this is a factor of some importance. On the other hand, we have a large number of measurements of these constants of cable insulation up to stresses that will produce failure during application for a period of a few minutes to a few hours, and in these samples find no change in properties of importance in this connection. It is perfectly practical to make a full investigation of these properties for any given material and to verify or disprove the application of this theory for any particular kind of material.

P. L. Alger: I should like to call attention to the analogy that seems to exist between the theory of cable insulation stress and the theory of the stress in a gun. The old idea of a gun was that when the pressure inside increased, failure occurred simply by stretching the periphery. You could figure the whole problem out by plane or two-dimensional theory. But later it was found that when you apply stress in any direction to a solid, a stress occurs also at right angles, so the problem becomes one of three dimensions.

It appears to me, therefore, that a study of the three-dimensional theory of failure of cylinders might illuminate some of the problems of cable insulation.

W. A. Hillebrand: In considering the mechanism of the breakdown of a dielectric there are several possibilities to be taken into account. Free electrons may be pulled out of the material itself, atoms may be disrupted by the electrostatic field imposed or additional ions may be formed by collision with free electrons present in impurities in the dielectric up to the point where a conducting stream is established.

The first of these requires electric intensities considerably in excess of the rupture value of dielectrics, and in the second case, the electric stresses rise to values several hundred times greater, so that both of these possibilities would seem to be ruled out of consideration. If this is true, the problem of producing a satisfactory dielectric resolves itself into one of eliminating impurities, chiefly air and water.

E. W. Davis (communicated after adjournment): The dielectric strength of solid insulating material cannot be stated as a definite value but can only be given within comparatively wide limits. The reason for this can be summed up in one word, homogeneity, or rather lack of homogeneity. The non-homogeneity may be mechanical,—*viz.*, impurities or treatment; it may be thermal, chemical, or electrical, or combinations of any or all of these.

In cables, this inherent erraticalness of dielectrics is further complicated by the nature of the electrostatic field. The uneven distribution of stress across the insulation tends to emphasize non-homogeneity still further.

It was recognized at an early date that, in a single-conductor cable, up to a definite point the addition of more insulation increased the dielectric strength of a cable; beyond this point, no apparent advantage was obtained by putting on more insulation; that is, the maximum stress as determined on thin insulation could not be applied to the calculation of voltage strength for thicker insulation.

In this present paper the author has attacked the single-conductor cable problem from the pyroelectric theory point of view, and has extended this theory to apply to the non-homogeneous field present.

There is no doubt that practically all breakdowns in dielectrics, at some point in the phenomena, are due to pyroelectric or local heating effects. In uniform fields the pyroelectric effect may be the only one present.

In irregular fields, however, the pyroelectric effect may be of a secondary nature and form the final step in the chain of events leading up to and ending at failure. The concentration of electrostatic flux beyond the ability of the dielectric to withstand would start, or cause to be started, abnormal heating effects of sufficient magnitude to begin the pyroelectric cycle and ultimately cause complete breakdown.

This brings us to the point considered by the author; that is, the "electrical elastic limit" or the critical point between stress and strain. It has been shown in the past that insulation can be "over-stressed" and permanently injured without causing actual breakdown; that is, the "elastic limit" has been exceeded but the cycle of events has been interrupted before actual breakdown has occurred. This would tend to point to that the pyroelectric effect, in some cases, is a secondary the conclusion phenomenon.

In a dielectric, the ratio of stress to strain is inversely proportional to the specific inductive capacity of the material and so long as this remains constant, the ratio of stress to strain also is constant. The elastic limit of a dielectric then is the point at which the direct proportionality of stress to strain ceases to hold. Above this point, if the stress is held constant and the strain increases, the dielectric constant must increase. This of course is based on a perfect dielectric in which no leakage currents or dielectric losses exist. All dielectrics, however, have conduction currents and losses under voltage which further complicate the problem by adding a heating effect. The increase of conduction current with stress is proportional to the stress up to the point where the heating and the negative coefficient of the dielectric cause an increase in conductivity and also where the increase of strain with stress becomes greater than the increase of stress. At such a point, failure will result.

This means that the electric "elastic limit," the pyroelectric effect and homogeneity are so tied into the mechanism of breakdown that all must be considered. The dielectric strength of insulation then may not be a definite value but rather a broad band wherein the various controlling phenomena exert accumulative effect upon the dielectric.

P. L. Hoover: It has been pointed out that certain assumptions have been made in the conversion of Wagner's data from potentials to stresses. I have assumed that a slab of dielectric of thickness t may be divided into elementary slabs of thickness $d\,t$, and that the voltage across any two of these elementary slabs is twice the voltage across one, if the current density is uniform. That seems to be logical but, of course, what seems logical may not be true.

W. A. Del Mar: The point I tried to raise there is that there may be limitations to that assumption. They seem to be perfectly correct as far as you have gone, but you have made us question how far you can go without going to a limiting point.

P. L. Hoover: There may be limitations. When breakdown voltage is plotted against thickness, we do not get, ordinarily, a linear relation. On the other hand, Wagner did find breakdown voltage proportional to thickness. Therefore, from Wagner's data, the assumption is justified and I have simply gone ahead and made it. Deviations from the linear relation between breakdown voltage and thickness must be accounted for, then by non-uniform fields, non-homogeneity of the insulation, etc.

It was also brought out that the volt—ampere characteristic will be different for every material and that in making calculations for the a-c. breakdown the a-c. characteristic should be used. Such is indeed the case. Wagner measured the d-c. characteristics of various materials and obtained a different curve for each material. All of the volt-ampere characteristics however, have the same general shape and there is no essential qualitative difference between them. Equation (1) will be different therefore for each material and the other equations will be changed correspondingly. Assuming that the theories advanced are correct, the contribution of this paper is not from data given on cables with insulation of a characteristic set forth by equation (1), but a method for calculating the breakdown voltage and the gradient in any cable with any insulation from a fundamental and characteristic equation of that particular insulation. The data given are to be regarded as illustrative of the method and relatively unimportant as compared to the significance of the method itself.

Mr. Wiseman has stated that according to theory the maximum b eakdown voltage is expected when r/R equals 0.434. It must be remembered that the theory to which he refers is that which accepts the logarithmic formula for the gradient in a cable. I have attempted to show that the logarithmic formula does not hold at high stresses and therefore the ratio $r/R = 0.434$ has no significance.

Mr. Hillebrand stated that the value of electric intensity required to pull an electron out of an atom or molecule is considerably in excess of the rupture value of dielectrics, and therefore rules out this phenomenon from consideration when discussing dielectrics. I cannot agree with that. If we are considering a single atom in space, or any number of atoms, providing they are far apart as compared to their actual size, then it is true that the field required to pull out an electron is considerably in excess of the rupture value of dielectrics. In solids or liquids, however, we do not have isolated molecules. The intermolecular fields are quite large and of the same order of magnitude as the intra-molecular fields. For this reason an electron may be removed from a molecule, passed on to the next molecule, and so on through the dielectric with an external field considerably weaker than that which would be required to extract an electron from the same molecule if it were isolated in space.

In regard to the effects of transients on breakdown, much can be said. The experiments of Prof. Kennelly and Mr. Wiseman, as cited in the paper, seem to show that small oscillations occur just before breakdown and cause breakdown to take place at a somewhat lower voltage than otherwise would be the case. However, as Mr. Del Mar stated, these data should be examined critically. In comparing breakdown values for large and small areas the question of the probability of finding weak spots should be considered. It seems to me that in the experiments of Kennelly and Wiseman the question of probability has been ruled out. They first measured the puncture voltage of some material using an electrode area of about 1 sq. cm. Then an electrode of 16 times this area gave a diminution of about 15 per cent in the puncture voltage. This same diminution was found regardless of whether the electrode was a single large plate or a group of 16 small electrodes connected together by a low resistance lead. This agrees with the predictions of the probability theory and this general effect of decreasing puncture voltage with increasing electrode area is often considered a strictly probability phenomenon. However, the probability theory received a serious jolt when Kennelly and Wiseman connected the 16 small electrodes together through a small resistance,—an ohm or so. When this small resistance was inserted between each electrode, there was no diminution in puncture voltage with increasing area. This is not in accord with the probability theory and an explanation must be found on some other basis; at least for these particular data.

To say that the probability theory is of no use in explaining phenomena of this kind would be going too far. If the material being tested was not very homogeneous, the probability factor undoubtedly would be large. The magnitude of the probability factor is therefore a variable and the importance of this factor in any particular set of data will have to depend on personal opinion unless conclusive experiments are performed to decide the case.

The peculiar effects that were found in puncturing the thermometer tubes have been ascribed to high-frequency phenomena. That such must be the case seems to follow from the fact that the effects observed are similar to those known to result from high-frequency pulses. The effects of heating and mechanical strains also seem to be ruled out by the fact that the tube was held very near the puncture voltage for half an hour. This gave ample time for heating and mechanical effects to show up but none was observed. As stated in the paper there is no evidence in this case to show whether the oscillations or pulses were set up just before breakdown or whether they were the result of breakdown.

It is easy to see how a small oscillation might cause dynamic rupture of the whole insulation. If we suppose that the particular cable or insulation is operating at a point on the positive slope but near the maximum of the volt-ampere characteristic, a small impulse superimposed on the existing stress might very easily carry the insulation over to a point on the negative slope of the curve. We would then have a state of unstable equilibrium, and dynamic rupture would follow.

It is for this reason that oils are particularly bad as a constituent of composite insulation. If the insulation as a whole is operating near the rupture point, the oil will probably be overstrained and small discharges will take place within the oil. Aside from any deterioration of the insulation due to these internal discharges, the stability of the insulation as a whole will be so disturbed that the operating voltage will be reduced materially.

Mr. Atkinson has discussed at length the effects of internal discharges in cables and impregnated paper insulation. Impregnated paper is not a homogeneous insulation, and as a result, the field is not strictly radial but has longitudinal and circumferential components. Furthermore, since the dielectric strength is less in a longitudinal or circumferential direction, due to the fact that the paper offers little or no barrier action to the motion of ions, it seems very likely, as is the case, that internal discharges will take place in a longitudinal or circumferen-

tial direction. These discharges are the case of "tree designs." They undoubtedly deteriorate the insulation and may lead to breakdown as described by Mr. Atkinson. I do not agree with Mr. Atkinson however, when he states that these discharges are "needle-points."

In order to have a discharge from one point to another, it is necessary to have a considerable quantity of charge at those two points. It seems unlikely that such an accumulation of charge exists within a cable insulation. The condition that more likely exists is that a certain region discharges into another region of lower potential. The flow from one region to the other may be quite concentrated and result in a charred path, but these discharges can not end at a point. They must spread out and discharge a finite volume of dielectric. We can not picture therefore, the needle-point as piercing it way through the insulation due to the high flux concentration at a point, for there is no point. Visual observations on discharges in oil support this view and so it seems that the needle-point concept must be modified. On the other hand, these internal discharges do lead to progressive deterioration due to the fact that the charred path becomes a conducting filament that connects the two regions. In this manner the low-potential regions will progress inward toward the conductor and the high-potential regions will progress outward toward the sheath. Dynamic rupture of the cable is the final result.

As regards the communication of Mr. Davis, I wish to state that I have not taken the pyroelectric point of view. I do believe that there are many cases wherein the heating effects are directly responsible for breakdown. On the other hand, I agree with Mr. Davis that there are many cases also in which the heating effects are of a secondary nature, if not entirely negligible.

Since the publication of this paper, it has been called to my attention that Fig. 1 does not check the original data of Wagner. This is due to a misprint in the source of my material which resulted in my taking an erroneous value for the area of the electrode. This means that equation (1) does not give the volt—ampere characteristic of the oiled paper that Wagner used. Equation (1), however, gives a curve that resembles the curves which Wagner actually did get and the conclusions arrived at in the paper are by no means invalidated. As stated before, it is the method and the qualitative nature of the conclusions that are most important.

TWENTY-FIFTH ANNIVERSARY OF THE BUREAU OF STANDARDS

The Bureau of Standards celebrated 25 years of service to the public, the industries, and the Government on December 4. The observance of this event was peculiarly fitting. On that day the staff kept "open house" and received all those who cared to take advantage of this opportunity of becoming acquainted with the bureau and its work. Probably 1500 people visited the laboratories. Among these were a large number who had never visited the bureau before, as well as many old friends and former members of the staff. A luncheon was served in the Industrial Building and throughout the day every effort was made to explain to the visitors the varied researches in progress in the laboratories.

In the evening a dinner was given by the staff at the New Willard Hotel. About 450 members and guests were present. Doctor Burgess, the Director, acted as toastmaster.

ILLUMINATION ITEMS

By Committee on Production and Application of Light

INDUSTRIAL LIGHTING ACTIVITY OF N. E. L. A.

The N. E. L. A. Bulletin for December, 1926 carries an article by Joseph F. Becker, Chairman of the Industrial Lighting Committee, dealing with industrial lighting campaigns conducted by central station members of that Association during the past year. Better lighting was provided for nearly 20 per cent of the prospects in 15 communities for which data are available. The average sales statistics involved are:

Added watts for each reflector installed	122
Average selling price per reflector	\$3.25
Average cost of wiring, accessories and installation per reflector	7.80

Industrial lighting campaigns were carried on during the year in over 1500 communities. In 20 such communities a total of 25,413 kilowatts were added to the industrial lighting load and a market was created for over two million dollars worth of electrical material and labor for the utilization thereof.

This commercial view of some of the results of industrial lighting progress conveys to the reader by implication some notion of the improved industrial efficiency probably wrought by these advances in lighting. Not only is more light used in the industries as a result of these activities, but in general the engineering of the illumination is conducted more intelligently, with beneficial effect in increased efficiency and decreased spoilage.

MEET THE WELL LIGHTED CAR

In comparatively few years, the modern motor car has evolved from a machine that was merely a motor driven carriage. Earlier automobiles provided merely the essentials of transportation. The chief concern was to make a car that would be dependable, one that would get you there and back. The motor car of today is not only highly dependable, refined in its mechanical features and smooth in performance, but is also characterized by beauty in line, finish, and appointments, and by features which make for greater ease, comfort, convenience, and safety in travel. This tendency is reflected to some extent in the lighting provisions. The average number of lighting units per car for all automobiles on our highways has been slowly increasing and is now nearly five and one-half what it was.

The earlier illuminants for automobiles did not lend themselves readily to the subdivision, control, and maintenance necessary to provide for all the lighting needs of the motorist. Hence the irreducible minimum of two headlamps and a rear lamp became the standard equipment. Electric battery generator systems of

lighting removed these limitations and made it possible at insignificant cost to add greatly to convenience, safety, and enjoyment in motoring at night.

For a long time the problems of headlighting were so pressing that the attention of the industry and of motorists generally was diverted from these other lighting equipments, and it is only very recently that it has come to be generally realized that lighting is the most neglected of all motor car appointments. The well lighted car has a total of from ten to fifteen lighting units. Not a single one of these equipments is of the variety of devices that have been used sometimes as much to decorate the car as to perform a lighting service. The value of every one has been demonstrated by long use on various cars. The total cost of all these added lighting units is less than that of many a single accessory of much less utility and value. The electrical systems on the cars provide amply for these additional lamps, since none are used for long periods of time. When they are needed, however, they perform a service out of all proportion to the small initial investment.

A few automobile manufacturers have shown the way with cars that are well lighted. It is the next step toward the more complete car for many others. To the automotive lighting industry and the trade, it is of no less interest that twenty million cars now on our roads should have a hundred million additional lighting equipments.

Depressible-beam lighting with the two-filament headlight lamp is revolutionizing headlighting practise. Car manufacturers have adopted it at a rate unprecedented by any other development in this art. Depressible-beam headlamps provide the usual long range driving beam which at the touch of a readily accessible switch is depressed through two or three degrees so that it is well below approaching driver's eyes, thereby providing all of the advantages of dimming without sacrificing the necessary road illumination.

This is bringing a demand from other drivers for similar equipment. The drivers of the twenty million cars now in service can enjoy most of the advantages of depressed-beam headlighting by using one or two auxiliary driving lights mounted on the front of the car just below or at the side of the headlamps. The driving lights should be equipped with lenses or reflectors which distribute the light along as well as across the road and they should be aimed so that they light the road for not more than 100 ft. ahead of the car. The switching arrangement should be such that the headlamps are dimmed when the auxiliary lights are turned on.

The safety and convenience value together with the requisite characteristics of the other lighting equipments for the well lighted car are shown above.—*Light*, November, 1926.

EUROPEAN LIGHTING PROGRESS DISCUSSED AT ROME

The first meeting of the International Union of Producers and Distributors of Electrical Energy was held September 21-26, 1926, in Rome. This Union was organized last year by three professional societies interested in the central station industry, representing France, Italy and Belgium. The program for its first meeting included principally papers on central station operation but one group dealt with the subject of illumination and another with the development of applications other than lighting.

Mr. Edward Imbs presented the general report on lighting, Mr. de Valbreuze dealt with the lighting practise in France, Mr. C. Clerici treated the subject of electric lighting in Italy and Mr. T. Czaplicki of Poland presented a paper on methods of evaluating incandescent lamp performance. Messrs. Imbs, de Valbreuze and Clerici (who recently visited this country) referred often to the practise and state of development abroad in comparison with our own.

In Italy the consumption of energy for lighting increased last year about 16 per cent as compared with 9 per cent in the case of the United States, but the consumption per capita there is only 17 kw-hr. as compared with 85 kw-hr. here. Considering that the United States consumption is only 50 per cent of what it might be, it is pointed out that Italian lighting is only one-tenth developed. Much the same thing applies to France; the increase in lighting there was about 13 per cent for the year 1925 but the consumption per capita for lighting was about 32 kw-hr. The work which has been in progress in the United States for many years to improve lighting is commented upon in relation with similar work now being done by a French and an Italian organization for the improvement of lighting. Through these organizations central stations, manufacturers of lamps and lighting equipment, contractors and decorators are being brought into close contact to promote better lighting. Mr. Imbs believes that it might be desirable to create a special section of the International Union to insure the proper exchange of information and direction of effort in the lighting field.

Mr. Clerici's paper gives very interesting detailed statistics regarding the consumption of energy for light and power in various sections of Italy covering many years. Milan has the highest per capita consumption for lighting of any of the Italian districts, namely 46.4. In recent years 8.5 per cent of the kilowatt-hours consumed have been for lighting.

Mr. Czaplicki analyzes carefully the important elements to be considered in evaluating Incandescent lamp performance. He is familiar with the U. S. specification practise and in general his conclusions are in substantial agreement with our own.

JOURNAL
OF THE
American Institute
of Electrical
Engineers

PUBLISHED MONTHLY BY THE A. I. E. E.
33 West 39th Street, New York
Under the Direction of the Publication Committee

Subscription: $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $10.50 to Canada and $11.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th day of the month for the issue of the following month.

The Winter Convention in New York February 7-11

Some of the finest technical sessions of recent years as well as other outstanding features will mark the coming Winter Convention of the Institute which will be held in New York, February 7-11, 1927, with headquarters at the Engineering Societies Building.

Excellent Technical Sessions

Among the timely technical subjects to be presented are the following:

Synchronous machine analyses
Synchronous converter theory
Losses in constant-current transformers, in synchronous machines and in armatures.
Plotting magnetic fields
Reactances which carry direct current
Standardization of power-system voltages
Cable characteristics
Oil breakdown
Dielectric absorption
Corona space charge
Circuit-breaker tests
Surges on transmission lines and cables
Rectifiers of electronic type
Telephony and telegraphy
Wire-drawing mills
A-c. elevators
Meter—scalibration and temperature compensation.

System-Voltage Standardization

One of the more important technical subjects will be the standardization of system voltages which will be presented in the session on Wednesday morning, February 9. This subject will be treated from different points of view in papers by members of the various branches of the electrical industry. The symposium will take into account not only the operating voltages of systems, but also the voltage ratings of generators, transformers, circuit breakers and other connected equipment and finally the utilization voltages.

Edison Medal Presentation

The Edison Medal which has been awarded to Dr. William D. Coolidge will be formally presented to him on Thursday evening, February 10. (An announcement regarding this award is published elsewhere in the Journal.)

Lecture by dr. Coolidge

Following the Edison Medal presentation on Thursday evening, Dr. Coolidge will give a lecture on some of the remarkable scientific researches now being made. Dr. Coolidge's recent developments on the cathode-ray tube have created widespread interest and his lecture will surely be a most attractive feature of the convention.

Presentation of John Scott Medal

The John Scott Medal, which is awarded annually by the City of Philadelphia, will be presented to Gustaf W. Elmen during the session on Friday morning, February 11. (An announcement regarding the award of this medal is given elsewhere in this issue.)

Smoker

An informal occasion for getting together will be offered in a smoker which will be held at the Hotel Astor on Monday evening, the first of the Convention. Some very talented entertainers will perform throughout the evening and a late supper will be served.

Dinner-Dance

An event which is anticipated with pleasure during each of the Institute Winter conventions is the dinner-dance. This year's dance, which will be held at the Hotel Astor on Wednesday evening, promises to be quite as enjoyable as those of previous years. An excellent dinner will be served and a splendid orchestra will make it pleasurable for all who attend.

Inspection Trips

Inspection trips to a number of interesting places are planned for Thursday morning. There is always something of timely interest in the laboratories and plants around New York City and special observation trips are being arranged.

Reduced Railroad Rates

Under the certificate plan a reduction in railroad fares is available to out-of-town visitors. Under this plan each person should request a certificate when purchasing a one way ticket to New York. Presentation of this certificate at Convention headquarters will entitle the purchaser to half-rate fare for the return trip by the same route provided there are 250 certificates registered at the Convention. When purchasing tickets members or guests should advise their ticket agents that they will attend the A. I. E. E. Convention and should ask for the certificates. Families of members attending the Convention are entitled to certificates also. On a few limited trains the return tickets purchased at reduced rates will not be honored. Tickets must be purchased within a limited number of days prior to the meeting and return tickets must be used within a limited time after the meeting. The limiting dates depend upon the location of the purchaser. Information on this and other details may be obtained from ticket agents. Immediately upon arrival in New York, certificates should be deposited with the endorsing officer at Convention headquarters.

All Visitors Should Get Certificates

Everyone should obtain a certificate, whether he will use it or not, for failure to do so may deprive others coming long distances of the saving in railroad fare made possible by this provision.

Convention Committee

The general committee appointed by President Chesney for this Convention is as follows: G. L. Knight, Chairman, H. H. Barnes, Jr., J. B. Bassett, H. P. Charlesworth, H. A. Kidder, R. R. Kime, E. B. Meyer and C. E. Stephens.

TENTATIVE PROGRAM OF WINTER CONVENTION FEBRUARY 7-11, 1927

Monday Morning, February 7

Registration
Committee Meetings

Monday, 2:00 P. M.

Technical Session

Synchronous Electrical Machines

Synchronous Machines—III, by R. E. Doherty and C. A. Nickle, General Electric Co.

Sub-synchronous Harmonics on M. M. F. Wave of Polyphase Windings, by Quentin Graham, Westinghouse Electric & Mfg. Co.

Transverse Reaction in Synchronous Machines, by J. F. H. Douglas, Marquette University.

Starting Performance of Synchronous Motors, by H. V. Putman, Westinghouse Electric & Mfg. Co.

Monday, 8:00 P. M.

Smoker and Entertainment

Tuesday, 10:00 A. M.

Technical Session

Electrical Machinery

(Synchronous Converters and Losses)

The Synchronous Converter—Theory and Calculations, by T. T. Hambleton and L. V. Bewley, General Electric Co.

Constant-Current Regulating Transformer Characteristics, by H. C. Louis and Arthur Albaugh, Consolidated Gas, Electric Light & Power Co.

Additional Losses of Synchronous Machines, by C. M. Laffoon and J. F. Calvert, Westinghouse Electric & Mfg. Co.

Reduction of Armature Copper Losses, by Ivan H. Summers, General Electric Co.

Tuesday, 2:00 P. M.

Technical Session

Magnetic Fields and Reactances

Graphical Determination of Magnetic Fields
Three Papers as Follows:

(*a*) *Theoretical Considerations*, by A. R. Stevenson, Jr., and R. H. Park, General Electric Co.

(*b*) *Comparisons of Calculations and Tests*, by E. E. Johnson, General Electric Co., and C. H. Green, Raytheon Mfg. Co.

(*c*) *Practical Applications to Salient-Pole Machines*, by R. W. Wieseman, General Electric Co.

Design of Reactances and Transformers Which Carry Direct Current, by C. R. Hanna, Westinghouse Electric & Mfg. Co.

Wednesday, 9:30 A. M.

Technical Session

Voltage Standards

Voltage Standardization of A-C. Systems from the Viewpoint of the Electrical Manufacturer, by H. R. Summerhayes, General Electric Co., and F. C. Hanker, Westinghouse Electric & Mfg. Co.

Voltage Standardization From a Consulting Engineer's Point of View, by R. E. Argersinger, Stone and Webster, Inc.

Standardization of Voltage Ratings for A-C. Power Systems and Equipment, by A. E. Silver and A. L. Harding, Electric Bond and Share Co.

Voltage Standardization as Related to Distribution Systems, by H. B. Gear, Commonwealth Edison Co.

Voltage Standardization and Its Relation to the Interconnected Companies of the Southeast, by H. J. Scholz, W. W. Eberhardt and S. M. Jones, Alabama Power Co.

The Suggested Transformer Voltage Standards and Their Relationship to Pacific Coast Practise, by Pacific Coast Electrical Association Subcommittee on Transformer Standardization, H. H. Minor, Chairman.

Standardization of Voltages, by A. Huber-Ruf, Brown Boveri Co. (Switzerland.)

Combined Light and Power Systems, for A-C. Secondary Networks, by Henry Richter, Westinghouse Electric & Mfg. Co.

Wednesday, 2:00 P. M.

Technical Session

Cables, Dielectrics and Corona

A New 132,000-Volt Cable Joint, by D. M. Simons, Standard Underground Cable Co.

Measurements on Cables and Insulators under A-C. and D-C. Stresses, by C. L. Kasson, Edison Electric Illuminating Company of Boston.

Oil Breakdown at Large Spacing, by D. F. Miner, Westinghouse Electric & Mfg. Co.

Maxwell's Theory of the Layer Dielectric, by F. D. Murnaghan, Johns Hopkins University.

Space Charge and Current in Alternating Corona, by C. H. Willis, Princeton University.

Wednesday, 7:00 P. M.

Dinner-Dance

Thursday, 10:00 A. M.

Inspection Trips

Thursday, 2:00 P. M.

Technical Session

Circuit Breakers and Surge Investigations

Tests on Oil Circuit Breakers, by Philip Sporn and H. P. St. Clair, American Gas and Electric Co.

Klydonograph Surge Investigation, by J. H. Cox, P. H. McAuley and L. G. Huggins, Westinghouse Electric & Mfg. Co.

Transmission-Line Voltage Surges, by J. H. Cox, Westinghouse Electric & Mfg. Co.

The Measurement of Surge Voltages on Transmission Lines Due to Lightning, by E. S. Lee and C. M. Foust, General Electric Co.

Thursday, 8:15 P. M.

Edison Medal Presentation

Lecture by Dr. William D. Coolidge

Friday, 10:00 A. M.

Presentation of John Scott Medal

Technical Session

Telephony, Telegraph and Wire Mills

A New Electronic Rectifier, by L. O. Grondahl and E. H. Geiger, Union Switch and Signal Co.

Measurement of Telegraph Transmission, by H. Nyquist, R. B. Shanck and S. I. Corey, American Telephone & Telegraph Co.

Telegraph Traffic Engineering, by H. Mason and C. J. Walbran, Western Union Telegraph Co.

Developments in the Manufacture of Copper Wire, by J. R. Shea and Samuel McMullan, Western Electric Co.

FRIDAY, 2:00 P. M.

TECHNICAL SESSION

A. C. ELEVATORS, METERS AND RECTIFIERS

A-C. Elevator Motor Drive, by E. B. Thurston, Haughton Elevator and Machine Co.

A Stroboscopic Method of Calibrating and Checking Watthour Meters, by H. P. Sparkes, Westinghouse Electric & Mfg. Co.

Compensation of Temperature Errors in A-C. Watthour Meters, by D. T. Canfield, Purdue University.

Three Regional Meetings Planned for First Half of 1927

Three regional meetings will be held by three Districts of the Institute during the months of March, April and May, respectively at Kansas City, Mo.; Bethlehem, Pa., and Pittsfield, Mass.

KANSAS CITY MEETING, MARCH 17-18

At Kansas City a two-day meeting will be held on March 17 and 18. For the technical sessions, some subjects of much interest to those in the District will be presented, including mercury arc rectifiers, automatic substations, supervisory control, electric welding of pipe lines, electrical drive in flour mills, railroad signaling, etc. The committee is also planning several interesting inspection trips, a dinner-dance, special entertainment for the ladies and other features to make the meeting most enjoyable.

BETHLEHEM REGIONAL MEETING, APRIL 14-16

The Regional Meeting of District 2 will be held in Bethlehem, Pa., April 14-16. Technical sessions will be held on the first two days and the third day will be devoted to trips. Among the technical subjects will be application of electricity in steel mills, cement mills and coal mines, voltage standardization, distribution losses, high-pressure turbines, transmission-line surges, mercury arc rectifiers, circuit breakers, induction motors and intercommunication systems. Other features of the meeting are also being developed.

PITTSFIELD REGIONAL MEETING, MAY 25-27

District No. 1 will hold a meeting this year in Pittsfield, Mass., on May 25, 26 and 27. The plans for the meeting are already being developed and a good program is promised. As part of the program it is planned to hold a meeting of Enrolled Students. This student meeting will be similar to the meeting held in Boston last year but it is thought that many benefits will result from holding it in conjunction with the regional meeting.

Future Section Meetings

Akron

Power-Factor Problems, by Frank Wallene. This talk will be accompanied by a demonstration in the Electrical Laboratory of the University of Akron. January 14.

The Electrification of the Rubber-Reclaiming Industry, by A. P. Regal, Philadelphia Rubber Co. February 18.

Boston

Research, by S. M. Kintner, Westinghouse Electric & Mfg. Co. January 20.

Cleveland

Mercury Arc Rectifier for Power Transmission, by D. C. Prince, General Electric Co. January 20.

Arc Welding, Its Present and Future, by J. F. Lincoln, Lincoln Electric Co. February 24.

Columbus

Railway Electrification. January 7.

Illumination. January 28.

Electric Ship Propulsion. February 25.

Pittsburgh

The Trend in Large Turbo Generator Developments, by representatives from the American Brown-Boveri Elec. Corp., the General Electric Co. and the Westinghouse Electric & Mfg. Co. January 11.

Pittsfield

Unusual Uses of Wood, by A. F. Koehler, Forest Products Laboratory, U. S. Dept. of Agriculture, University of Wisconsin. January 18.

Horticulture, by E. I. Farrington, Secretary, Massachusetts Horticultural Society, February 1.

Petroleum, by R. L. Welch, Secretary, American Petroleum Institute. February 15.

The Quest of the Unknown, by Prof. H. B. Smith, Worcester Polytechnic Institute. January 13.

Relaying of Power Systems, by Robert Treat, General Electric Co. February 8.

St. Louis

Banking of Transformers, by M. T. Mitschrich, Moloney Electric Co. January 19.

Recent Developments of the Telephone Industry, by a member of the Bell Telephone Laboratories. February 16.

Sharon

Photographs by Wire. January 4.

The Pymatuning Dam. February 1.

Southern Virginia Section

State Highway Construction, by H. G. Shirely, Chairman, State Commission;

Present Tendencies in Power Station Design, by Vern E. Alden, Stone & Webster, Inc., and

The Activities of the American Engineering Council, by L. W. Wallace, Secretary, American Engineering Council. A talk will also be given at dinner by S. Heth Tyler, Mayor of Norfolk. All day meeting, joint with A. S. M. E. and A. S. C. E. Inspection trip to the Ford Motor Company. January 21.

Vancouver

Visit to Dunbar Automatic Substation. Demonstration of operation by R. L. Hall. January 11.

University of British Columbia Night. Papers by students. February 1.

Central Station Design

To be Discussed by New York Sections of A. I. E. E. and A. S. M. E.

A joint meeting of the New York Section of the American Institute of Electrical Engineers with the Metropolitan Section of the American Society of Mechanical Engineers will be held on Wednesday evening, January 19, 1927 at 8:00 o'clock p. m., in the Auditorium of Public Service Terminal, 80 Park Place, Newark, N. J.

At this meeting it is proposed to have a general discussion of the outstanding features of modern central station design.

Messrs. E. B. Ricketts and R. H. Tapscott of the New York Edison Company will speak on the mechanical and electrical features respectively of the new East River Station and Messrs. R. J. S. Pigott and W. R. Smith of Public Service Production Company will speak on the corresponding features of the Kearney Station of Public Service.

The talks will not be restricted to a dry recital of facts as to the capacities and types of installed apparatus but will discuss in detail the engineering features underlying general design and arrangement of both plants.

It is believed that the general subject of bulk generation of electric power will appeal to practically every engineer in the metropolitan zone and that in consequence the joint meeting will be well attended.

The meeting will be preceded by a get-together dinner to be held at 6:30 o'clock p. m., at the Robert Treat Hotel, located on Park Place, Newark, about midway between the Hudson and Manhattan Tube Station and Public Service Terminal. The charge for the dinner will be $1.50 per cover.

A. I. E. E. Nominations

The National Nominating Committee of the Institute met at Institute headquarters, New York, December 9, and selected a complete official ticket of candidates for the Institute offices that will become vacant August 1 1927.

The committee consists of fifteen members, one selected by the executive committee of each of the ten Geographical Districts, and the remaining five elected by the Board of Directors from its own membership.

Those present were: C. A. Adams, Cambridge, Mass.; O. B. Blackwell, New York, N. Y.; H. P. Charlesworth, New York, N. Y.; W. P. Dobson, Toronto, Ont.; C. A. Heinze, Los Angeles, Calif.; C. R Higson, Salt Lake City, Utah; J. E. Kearns, Chicago, Ill.; G. L. Knight, Brooklyn, N. Y.; E. B. Merriam, Schenectady, N. Y.; Walter H. Millan, St. Louis, Mo.; I. E. Moultrop, Boston, Mass.; Harold Pender, Philadelphia, Pa.; A. M. Schoen, Atlanta, Ga.; E. C. Stone, Pittsburgh, Pa.; and National Secretary F. L. Hutchinson. Professor Comfort A. Adams was unanimously elected chairman of the committee.

The following is a list of the official candidates.

FOR PRESIDENT

Bancroft Gherardi, Vice-President and Chief Engineer, American Telephone and Telegraph Company, New York, N. Y.

FOR VICE-PRESIDENTS

Middle Eastern District: J. L. Beaver, Associate Professor of Electrical Engineering, Lehigh University, Bethlehem, Pa.

Southern District: C. O. Bickelhaupt, Vice-President, Southern Bell Telephone and Telegraph Company, Atlanta, Ga.

North Central District: O. J. Ferguson, Dean, College of Engineering and Professor of Electrical Engineering, University of Nebraska, Lincoln, Nebr.

Pacific District: E. R. Northmore, Superintendent of Electric Distribution, Los Angeles Gas & Electric Corp., Los Angeles, Calif.

Canada District: A. B. Cooper, General Manager, Ferranti Electric Limited, Toronto, Ont.

FOR MANAGERS

F. C. Hanker, Manager, Central Station Engineering, Westinghouse Electric & Manufacturing Company, E. Pittsburgh, Pa.

H. P. Liversidge, Vice-President and General Manager, Philadelphia Electric Company, Philadelphia, Pa.

E. B. Meyer, Chief Engineer, Public Service Production Company, Newark, N. J.

FOR TREASURER

George A. Hamilton, Elizabeth, N. J. (re-nominated).

The Constitution and By-Laws of the Institute provide that the nominations made by the National Nominating Committee shall be published in the January issue of the Institute Journal, and provision is made for independent nominations as indicated below:

CONSTITUTION

Sec. 31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the National Secretary when and as provided in the By-Laws; such petitions for the nomination of Vice-Presidents shall be signed only by members within the District concerned.

BY-LAWS

Sec. 22. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with Article VI, Section 31 (Constitution), must be received by the Secretary of the National Nominating Committee not later than February 15 of each year, to be placed before that Committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the National Nominating Committee in accordance with Article VI of the Constitution and sent by the National Secretary to all qualified voters during the first week in March of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

National Nominating Committee
By F. L. Hutchinson,
Secretary

Bancroft Gherardi

Mr. Gherardi was born in San Francisco, California, April 6, 1873. He was graduated with the Degree of B. S. from the Polytechnic Institute of Brooklyn in 1891, and from Cornell University with the Degree of M. E. 1893 and Degree of M. M. E. in 1894.

Mr. Gherardi entered the employ of the New York Telephone Company in 1895 and in 1899 was made Traffic Engineer of that company. In 1901 he became Chief Engineer of the New York and New Jersey Telephone Company, serving in that capacity until 1906, when he was made Assistant Chief Engineer of the New York Telephone Company and New York and New Jersey Telephone Company. In 1907 he was appointed Equipment Engineer of the American Telephone and Telegraph Company and in 1909 Engineer of Plant, in which capacity he served until 1918, when he was appointed Acting Chief Engineer and shortly thereafter Chief Engineer. In April 1920, he became Vice-President and Chief Engineer of the American Telephone and Telegraph Company.

Mr. Gherardi's activities with the American Institute of Electrical Engineers are as follows: Associate 1895; Fellow 1912; Manager 1905-8—1914-16; Vice-President 1908-10. He has served upon various committees including the Edison Medal, Telephony and Telegraphy, Papers, Finance, Membership, Organization of Technical Committees, Constitutional Revision and Research. He represents the Institute on the U. S. National Committee of the International Electrotechnical Commission and the United Engineering Society. At the present time, Mr. Gherardi is a Vice-President and Chairman of the Finance Committee of the United Engineering Society and a Member of the Engineering Foundation. He is also a Member of the American Society of Mechanical Engineers, New York Electrical Society and the Franklin Institute.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 10, 1926.

There were present: President C. C. Chesney; Past Presidents M. I. Pupin and Farley Osgood; Vice-Presidents A. G. Pierce, W. P. Dobson, H. M. Hobart, and B. G. Jamieson; Managers H. P. Charlesworth, J. B. Whitehead, M. M. Fowler, H. A. Kidder, E. C. Stone, I. E. Moultrop, and H. C. Don Carlos; National Secretary F. L. Hutchinson.

The minutes of the Directors' meeting of October 15, 1926, were approved as previously circulated to the members of the Board.

The Board ratified action of the Executive Committee, under date of November 19, 1926, on applications for Student enrolment, admission to membership, and transfer from one grade of membership to another.

Reports were presented of meetings of the Board of Examiners held November 16 and December 7, 1926, and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following actions were taken upon pending applications: 194 Students were ordered enrolled;

82 applicants were elected to the grade of Associate; 3 applicants were reelected to the grade of Associate; 1 applicant was reinstated to the grade of Associate; 13 applicants were elected to the grade of Member; 6 applicants were transferred to the grade of Fellow; 52 applicants were transferred to the grade of Member.

Approval by the Finance Committee, for payment, of monthly bills amounting to $22,518.81, was ratified.

Upon application, and upon the recommendation of the Committee on Student Branches, authorization was granted for the establishment of a Student Branch of the Institute at the Mississippi Agricultural and Mechanical College, A. & M. College, Miss.

The Secretary advised that the John Scott Medal for 1926 had been awarded to Mr. Gustaf W. Elmen, a Member of the Institute. This medal is awarded annually by the Board of Directors of City Trusts of the City of Philadelphia, which makes a practise of presenting the medal at some meeting of an organization of which the medalist is a member; and the Secretary had been approached by Mr. Elmen and the secretary of the Board of Directors of City Trusts, Philadelphia, in regard to presenting the medal to Mr. Elmen during the Winter Convention of the Institute to be held in February 1927. The Board voted its approval of the presentation of the John Scott Medal to Mr. Elmen during the Winter Convention of the Institute.

In accordance with recommendations of the officers of the Pacific District, the Board approved holding the 1927 Pacific Coast Convention at Del Monte, California, September 13-16, and a convention committee with Vice-President P. M. Downing as chairman, was appointed.

The resignation of Mr. H. S. Osborne, former chairman of the A. I. E. E. Standards Committee, as a representative of the Institute on the American Engineering Standards Committee, was presented and accepted, and Dr. J. F. Meyer, present chairman of the A. I. E. E. Standards Committee, was appointed to fill Mr. Osborne's unexpired term. Mr. Osborne was thereupon appointed an alternate on the A. E. S. C. for the year 1927.

In accordance with recommendations of the Standards Committee, the Board, voted (1) to approve a report on Standards for Hard Drawn Aluminum Conductors, with the understanding that it will be transmitted to the American Engineering Standards Committee for approval; (2) to approve a revision of Section 9, A. I. E. E. Standards for Induction Motors and Induction Machines in General, to become effective January 1, 1927; (3) to approve report on Electrical Measuring Instruments, for publication as an A. I. E. E. Standard (No. 39); (4) to authorize submission to the A. E. S. C. for approval as American Standards, A. I. E. E. Standards for Electric Arc Welding Apparatus (No. 38) and Electric Resistance Welding Apparatus (No. 39).

A communication was presented, requesting the Institute to send a respresentative to a conference to be held at Syracuse, N. Y., December 29, to consider the organization of a New York State Engineering Council, and the Board voted to refer the matter to the New York State Sections of the Institute, with the request that they each send a representative to the conference.

The Secretary reported 810 Associates, 45 Members, and two Fellows delinquent in the payment of dues for the fiscal year which ended April 30, 1926, and was authorized to remove from the membership list on December 31, 1926, the names of all those whose dues remain unpaid at that time and who have not indicated a desire to continue membership, requesting an extension of time for payment of the dues.

A suggestion that a Great Lakes trip be arranged to follow immediately after the Summer Convention at Detroit, June 20-24, was considered, and it was agreed that the president would appoint a committee to investigate the possibilities of such a trip.

Other matters of importance were discussed, reference to which may be found in this and future issues of the Journal.

Edison Medal Awarded to William D. Coolidge

The Edison Medal for the year 1926 has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to Dr. William D. Coolidge, "for the origination of ductile tungsten and the fundamental improvement of the X-ray tube."

The Edison Medal was founded by associates and friends of Thomas A. Edison, and is awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts," by a committee consisting of twenty-four members of the American Institute of Electrical Engineers.

The following men have been recipients of the medal: Elihu Thomson, 1909; Frank J. Sprague, 1910; George Westinghouse, 1911; William Stanley, 1912; Charles F. Brush, 1913; Alexander Graham Bell, 1914; Nikola Tesla, 1916; John J. Carty, 1917;

William D. Coolidge

Benjamin G. Lamme, 1918; W. L. R. Emmet, 1919; Michael I. Pupin, 1920; Cummings C. Chesney, 1921; Robert A. Millikan, 1922; John W. Lieb, 1923; John White Howell, 1924; Harris J. Ryan, 1925.

William David Coolidge, assistant director of the research laboratory of the General Electric Company, and physical chemist, was born in Hudson, Massachusetts, October 23, 1873, the son of Albert Edward and M. Alice Coolidge. Dr. Coolidge is a graduate of the Massachusetts Institute of Technology, B. S., 1896, and of the University of Leipzig, Ph. D., 1899. He has been assistant in physics, instructor in physical chemistry and assistant professor of physico-chemical research of the Massachusetts Institute of Technology. Dr. Coolidge became associated with the General Electric Company in 1905 and was made assistant director of the research laboratory in 1908. In 1914 he was awarded the Rumford Medal for invention and applications of ductile tungsten. Dr. Coolidge is a member of the American Chemical Society; American Electrochemical Society; American Physical Society; American Institute of Electrical Engineers; American Academy of Arts and Sciences; Washington Academy

of Sciences. He is an honorary member of the American Roentgen Ray Society; American Radium Society; Radiological Society of North America; Röentgen Society (of England); Societe de Radiologie Medicale (of France) and Nordick Forening for Medicinsk Radiologi.

The medal will be presented to Dr. Coolidge on the evening of February 10, during the Winter Convention of the Institute in New York, February 7-11, 1927.

John Scott Medal Awarded to G. W. Elmen

The John Scott Medal has been awarded to Gustaf W. Elmen for the invention of the nickel-iron alloy of very high magnetic permeability known as "permalloy." Mr. Elmen is a Member of the Institute and Electrical Engineer in the Bell Telephone Laboratories. The medal will be presented to Mr. Elmen during the coming Winter Convention of the A. I. E. E. on Friday morning, February 11.

This medal was established in 1916 by John Scott, of Edinburgh' Scotland, who bequeathed to the City of Philadelphia a fund to be used for furnishing cash premiums and medals to those who make useful inventions.

The awards are made annually and for 1926 three medals were awarded, each with a premium of $1000. The other recipients were Dr. Harvey C. Hayes, Bureau of Engineering, U. S. Navy, for the invention of a sonic depth finder and other submarine signaling devices; and Admiral Ralph Earle, formerly Chief of the Bureau of Ordnance, U. S. Navy, for invention of the 14-in. railway gun mounts and the mine barrage across the North Sea used during the World War.

Standardization Policy Amplified by Board of Directors

At its December 10th meeting, the Board of Directors of the Institute gave further consideration to the subject of policy and procedure as regards electrical engineering standards. The Board extended its action of February 9, 1926, dealing with the formulation of the Institute's standardization policy, so that the complete procedure is now outlined as follows:

As Adopted February 9, 1926

Whereas this Board has, by various actions taken in recent years, adopted a definite policy regarding the relation of the Institute to standardization activities, and

Whereas it appears desirable to restate this policy from time to time, therefore be it

Resolved that the following brief statement of this policy be and hereby is adopted for publication and for transmission to the members of the Standards Committee and to representatives of the Institute upon any other committees, or upon joint bodies, dealing with the formulation of standards:

Policy of A. I. E. E. Regarding the Formulation of Standards

1. To continue to develop, publish and maintain in the name of the Institute, electrical standards as it has done for the past 25 years.

2. That in doing this work the Institute will continue to avail itself to the fullest degree of the assistance of others —both individuals and organizations—with a view to serving the interests of all who may be properly concerned in this work.

3. That Standards after having been developed by the Institute in accordance with (1) and (2) and adopted by the Board of Directors as Institute Standards will be presented to the American Engineering Standards Committee for approval by them as American Standards when, in the opinion of the Institute, such a step is proper.

4. That such presentation to the American Engineering Standards Committee for consideration for approval as American Standard will be done in full conformity with the Constitution, By-Laws and Rules of Procedure of the American Engineering Standards Committee, which Committee the Institute was instrumental in initiating and has continued to and does now endorse and support.

5. That when and if standards of the A. I. E. E. have been further advanced to the stage of being designated as "Approved as American Standard by the American Engineering Standards Committee," they shall continue to be printed as standards of the A. I. E. E., with a statement of approval by the American Engineering Standards Committee added to the title page of each particular standard.

As Adopted December 10, 1926

Inasmuch as American Engineering Standards Committee was, in its inception, professional in character and a creature of the national professional societies, and

In the belief that the commission to a professional body of the definite responsiblity for serving all interests will provoke and insure a spirit of broad cooperation, and

To prevent the possibility of jurisdictional disputes inconsistent with the character of professional and commercial organizations alike, and in accordance with recommendations of the Standards Committee to the Board, it is moved

That the Board of Directors of the Institute hereby extends its action of February 9, 1926 affecting the preparation and sponsorship for standards under A. E. S. C. procedure to include the following principles.

1. The preferred procedure in the preparation of a standard shall be to commit such duty to the appropriate professional body, if any be existent, provided such professional body shall undertake to ascertain the desires of all interested bodies or groups, and so far as possible comprehend them within its standard.

2. In general, sole sponsorship by the appropriate professional body is the preferred means of adoption of a standard under any form of American Engineering Standards Committee procedure.

3. The Board will view with satisfaction any proper steps taken in the direction of effectuating, formally or otherwise, the two foregoing principles.

Revision Approved of Standards for Induction Motors and Induction Machines in General

At the meeting of the Board of Directors of December 10, 1926, the recommendation of the Standards Committee of December 3rd, that Section 9, A. I. E. E. Standards for Induction Motors and Induction Machines in General, be revised was approved. The Working Committee under the chairmanship of P. M. Lincoln, which developed the Standards, has approved the revision, effective as of January 1, 1927 as follows:

A. I. E. E. Standards No. 9—January 1926, Paragraph 9-310 $I^2 R$ Loss:

Reword second paragraph of "(b) Polyphase Induction-Motor Rotor" as follows:

"In slip-ring motors, in which the slip cannot be directly measured by loading, *due to large size or for other reasons*, the rotor $I^2 R$ loss shall be determined by direct resistance measurement; the rotor . . . etc.

Italics indicate inserted clause.

Paragraph 9-312 Brush Contact Loss.

Add a footnote to 9-312, as follows:

"When the rotor $I^2 R$ loss is calculated from the slip, in accordance with paragraph 9-310 (b), the slip being determined in such a way that the brush contact losses are included in the $I^2 R$ losses as calculated, losses corresponding to the conventional values specified in this paragraph should not be added.

"When the loss is determined by direct resistance measurement which does not include the resistance of the brushes and brush contacts the conventional values given in this paragraph should apply."

A. I. E. E. Standards in Spanish

The A. I. E. E. Standards for Alternators, Synchronous Motors and Synchronous Machines in General are now available in Spanish. This section of the Standards, which is No. 7 in the listing of A. I. E. E. Standards, is the first of a series of about 20 which will eventually appear in Spanish.

As the result of a joint request to the Department from industry and from the A. I. E. E., the Bureau of Foreign and Domestic Commerce of the Department of Commerce is publishing this series of translations of electrical standards. It is hoped that the venture will lead to development of a greater knowledge and use of the A. I. E. E. electrical standards in the Spanish speaking countries. The Institute is furnishing the Spanish manuscript—translations being made under the direction of a committee headed by Dr. C. O. Mailloux. All the Spanish editions will be in similar form and of the same size as the Standards pamphlets issued by the Institute. Copies of Spanish editions may be obtained from the Superintendent of Documents Government Printing Office, Washington, D. C. at a price of 10 cents per copy. Special rates on large quantities.

Proposed Revision of A. I. E. E. Standards for Alternators, Synchronous Motors and Synchronous Machines in General

At a meeting of the Standards Executive Committee December 3, 1926, a revision of Section 7, A. I. E. E. Standards for Alternators, Synchronous Motors and Synchronous Machines in General was suggested. This revision originated in a sub-committee of the Committee on Electrical Machinery and consists in the addition to Section 7 of a paragraph entitled "Calculation of Natural Frequency for Synchronous Motors Direct Connected to Reciprocating Machinery." This addition is of entirely new matter and would probably be inserted between paragraphs 7-300 and 7-350. The Standards Committee directed that notice of the suggested revision be published in the Journal and urgently requests that any comments or suggestions be forwarded as soon as possible to the Secretary of the Standards Committee, A. I. E. E., 33 West 39th St., New York City. The text of the proposed paragraph follows:

Calculation of Natural Frequency for Synchronous Motors Direct Connected to Reciprocating Machinery.—

a. The natural frequency shall be expressed in cycles per minute.

b. Synchronizing power shall be defined as the rate of change of power with respect to the displacement angle expressed in kilowatts per electrical degree. It shall be represented by P_s.

Note I. The value of P_s as given by manufacturers for any particular machine shall be that applying to rated load under steady conditions of operation.

Note II. The displacement angle is the phase lag or lead, in electrical degrees, of the rotor with respect to the line voltage.

c. The formula for natural frequency shall be expressed as follows:

$$F = \frac{266{,}500}{\text{R. P. M.}} \sqrt{\frac{P_s \times f}{W\, R^2}}$$

where

F = Natural frequency in cycles per minute
R. P. M. = Revolutions per minute
P = Synchronizing power as defined in *b*.
f = Cycles per second
W = Weight in lb. of rotor complete
R = Radius of gyration in feet.

A. I. E. E. Welding Standards to be Submitted for Approval as American Standards

By action of the Standards Executive Committee at their meeting of December 3, and subsequent approval by the Board of Directors of the Institute on December 10, 1926, two sections of the A. I. E. E. Standards were ordered submitted as American Standards to the American Engineering Standards Committee. The sections referred to are as follows: No. 38, Standards for Electric Arc Welding Apparatus (March, 1925); and No. 39, Standards for Resistance Welding Apparatus (Revised September, 1926). Both of these Welding Standards were developed by a representative working committee of the Standards Committee under the chairmanship of F. M. Farmer and, in accordance with the regular practise of the Standards Committee, received wide distribution in report form for purposes of criticism and suggestion before finally approved as A. I. E. E. Standards.

Members for Life

The Constitution of the Institute provides that the Board of Directors may exempt from future annual dues, any Fellow, Member or Associate who has paid dues for thirty-five years or shall have reached the age of seventy after having paid dues for thirty years. The Board has voted that this group be designated "Members for Life."

At the Directors' Meeting on December 10, a tribute was paid to the loyalty and valuable services of these members, who were so active in upbuilding the Institute in its earlier days, and it was voted that this honor list of "Members for Life" be published in the Journal as follows:

W. S. ANDREWS, Schenectady, N. Y.
ADAM BOSCH, Wyoming, N. J.
C. S. BRADLEY, New York, N. Y.
MAURICE COSTER, New York, N. Y.
W. H. DONNER, Philadelphia, Pa.
H. B. GALE, Natick, Mass.
WILLIAM MAVER, Jr., New York, N. Y.
E. L. NICHOLS, Ithaca, N. Y.
J. D. OTTEN, Amsterdam, Holland
E. F. PECK, Hampton, Va.
RALPH W. POPE, Great Barrington, Mass.
CHARLES, W. PRICE, New York, N. Y.
EDWARD P. ROBERTS, Lakewood, O.
ALMON ROBINSON, Lewiston, Me.
W. A. ROSENBAUM, New York, N. Y.
THEODORE STEBBINS, New York, N. Y.
NIKOLA TESLA, New York, N. Y.
WILLIAM S. TURNER, Portland, Ore.
C. R. Van TRUMP, Wilmington, Del.
FREMONT WILSON, New York, N. Y.

National Exposition of Power and Mechanical Engineering

The Fifth National Exposition of Power and Mechanical Engineering was a tremendous success. It registered strides of progress throughout the entire field of the design of all types of mechanical equipment.

In the field of power generation the Exposition displayed many novelties. A large number of electrically, hydraulically and pneumatically operated valves were shown for operations up to 650 lb. pressure and 750 deg. fahr. The novelty in this field was a swing-gate valve which occupies much less space than the present form.

In the field of control there was one adopting an electrical method of varying the fuel and air supply in proportion to a direct current which was varied, in turn, by steam pressure.

Other equipment of interest to power plant operators was a complete service of diagrams of condensers, air motors, air filters, pumps to operate against high pressures and stokers. In addition there were electric gas analyzers, electrically-operated safety valves, and two types of ventilated motors for operating in a dust-laden atmosphere.

Other classes of exhibits which should be mentioned are machine tools, shop equipment, coal handling and ash handling devices, conveying machinery, illuminating equipment for factories and power houses, and packings.

The plans are already under way for the holding of the Sixth Power Show from December 5 through 10, 1927.

Engineering Education

An important step in the progress of the investigation of engineering education was taken at a joint conference held in Washington, D. C., on November 18 and 19, under the auspices of the Board of Investigation and Coordination and the Division of Deans and Administrative Officers of the Society for the Promotion of Engineering Education. On this occasion the Board presented the first installment of its Report and proposed a plan for a new phase of activity in the colleges to be directed to putting the findings of the investigation into effect. The Report and the proposed plan for further activity received the hearty endorsement of the conference.

The results of the investigation are being published in two forms; one is a series of Bulletins setting forth the results of the several fact-finding studies; the other is a series of Reports embodying the findings and recommendations. These publications may be obtained at a nominal price from the Lancaster Press, Prince and Lemon Streets, Lancaster, Pennsylvania. The following publications have been issued up to the present time:

Preliminary Report of the Board of Investigation and Coordination....20 cents.
Preliminary Report of the Director to the Board and to the Society....15 cents.
Summary of the Fact-Gathering Stages of the Investigation....15 cents.
Bulletin No. 1, Engineering Students at the Time of Entrance to College....20 cents.
Bulletin No. 2, Admissions and Eliminations of Engineering Students....20 cents.
Bulletin No. 3, Engineering Graduates and Non-Graduate Former Students....20 cents.
Bulletin No. 4, Engineering Teaching Personnel....20 cents.
Bulletin No. 5, Supplementary Activities of Engineering Colleges....15 cents.
Bulletin No. 6, Costs of Engineering Education....15 cents.
Bulletin No. 7, Engineering Degrees....15 cents.
Bulletin No. 8, A Study of a Group of Electrical Engineering Graduates....15 cents.
Bulletin No. 9, A Summary of Opinions Concerning Engineering Curricula....20 cents.

The Report of the Board advises against any large degree of specialization for undergraduates and outlines a common core of subject matter which may well occupy about two-thirds of the time in all engineering curricula. It recommends a larger provision for specialized training after graduation and proposes, as one means to that end, the development of post-scholastic training by extension methods. The recommendation is made that specific training in administration and management be given, but as a complement rather than an alternative to a thorough grounding in applied science. A separate curriculum in management is not advised.

Other recommendations favor more adequate treatment of economics and the principles and technique of engineering economy, a more selective scheme of admission, more distinctive treatment of the more highly gifted students, more closely restricted promotion beyond the first two years with suitable recognition of those who reach only this goal, and more positive measures for the recruitment and development of engineering teachers.

Eleven additional Bulletins are now in preparation and the Board will issue further installments of its Report from time to time.

Annual Meeting of Civil Engineers

Announcement of the coming Annual Meeting of the American Society of Civil Engineers as recently issued gives full details of the pleasure and profit in store for those who plan to attend. In general, it will be noted that the arrangement of the sessions follows the program that has been so successful in past years.

Doubtless the entertainment and smoker on Thursday will prove an attraction, and certainly no one who was present last year will want to miss the sequel of Framem Reilly's engineering career. To any who did not become acquainted with this illustrious gentleman and well-known engineer then, it is enough to say that his experiences contain a real lesson to all his fellows.

The all-day excursion follows the general policy of years gone by. The social advantages of a trip by special train, with an enjoyable lunch, followed by numerous engineering inspection trips have attracted wide and favorable comment.

For the benefit of the Local Committee on Arrangements it is requested that every member forward his ticket order as promptly as possible.

Annual S. A. E. Dinner

About 1000 members and guests are expected to attend the annual dinner of the Society of Automotive Engineers, which is to be held at the Hotel Astor, January 13th. The speakers on the program have not yet been announced, but it is fair to assume that they will be worthy of the occasion and par excellence in quality. Election of the new president of the Society for 1927 will take place, J. H. Hunt, head of the electrical division of the General Motors Corporation Research Laboratories being the chosen nominee. Mr. Hunt has been a member of the A. I. E. E since 1907.

James H. McGraw Honored

A dinner at which industrialists, engineers and scientists from all over the United States were present was tendered to James H. McGraw, president of the McGraw-Hill Publishing Company the evening of December 17th at the Astor Hotel on the occasion of his 66th birthday and his 40th year in the service of engineering and industry. Secretary Hoover, Thomas A. Edison, Gen. Guy E. Tripp, Chairman of the Board of the Westinghouse Electric & Mfg. Co., Gerard Swope, President of the General Electric Company and Owen D. Young, Chairman of the Board of the General Electric Company were members of the sponsoring committee.

The speakers, representatives of the fields to which the fifteen publications headed by Mr. McGraw are devoted, spoke briefly, Gen. Tripp as the representative of the electrical manufacturing industry; Dean Dexter S. Kimball of the Cornell University School of Engineering spoke on behalf of engineering; Charles L. Edgar, President of the Edison Electric Illuminating Company, of Boston, for the power industry, and Willits B. Sawyer, President of the American Electric Railway Association, for the electric railway industry. John W. Lieb, Vice President and General Manager of the New York Edison Company was toastmaster.

Those who served on the committee were J. J. Carty, Vice-President American Telephone and Telegraph Company; Simon Guggenheim; John Hays Hammond; William Barclay Parsons; George Otis Smith, Director of the U. S. Geological

Survey; Sidney Z. Mitchell; Fred R. Low, editor of Power; Samuel Insull; Adolph S. Ochs; William J. Dewart; Karl A. Bickel; Dr. Livingston Farrand, President of Cornell University, and Nicholas F. Brady. Thomas A. Edison was Honorary Chairman, and Arthur Williams, Vice President New York Edison Company, was Chairman.

Metric System Urged Before Senate Committee

Representatives of the Metric Association of New York and other scientific organizations appeared before the Senate Committee on Commerce, December 10th, in support of Senate Joint Resolutions No. 105 and No. 107.

Resolution No. 105 authorizes the Director of the Bureau of Standards to conduct a thorough investigation and study to determine the advisability of adopting the metric system for general use in the United States following which he is to initiate and carry out any plans which he may develop for the general and common use of the system in this country.

Senate Joint Resolution No. 107 authorizing the Department of Commerce to establish commodity quantity units for general use in merchandising after 1935, standardizing the yards, the meter, the quart, the liter, the pound in five hundred grams, decimally divided. The representatives of organizations favoring the measure have plead their case and it is understood that those who are opposed to the measure will be given a hearing after the holidays.

Pay of Federal Judges Increased

The bill in which engineers have long been interested, providing for increased salaries for all Federal Judges, became a law when it passed the House of Representatives December 9, and was signed by the President on December 13. The engineers' interest in the measure was due primarily to a hope that the increased salary would keep competent men on the Federal benches, where all patent cases are adjudicated.

The new salary range for judges under this measure is $20,500 for the Chief Justice of the Supreme Court to $10,000, annually, for the judges of the district courts.

Strathcona Memorial Fellowships

There are available through Yale University, five yearly scholarships of $1000 each, designed to stimulate advanced study in transportation, with special regard to engineering features of railroad construction, equipment and operation and the study of transportation by water, highways and aviation.

Applications should be submitted by March 1, 1927, men who have received their first college degree being elegible. Full details, with proper application blanks, may be obtained from the Dean of the Graduate School, Yale University, New Haven, Conn.

The John Fritz Medal Awarded

On the evening of December 7th formal award of the John Fritz Gold Medal was made to Elmer A. Sperry, President of the Sperry Gyroscope Company and Charter Member of the Institute. The occasion was honored by such speakers as William L. Saunders, Chairman of the Naval Consulting Board of the United States, Rear Admiral Bradley A. Fiske, United States Navy, retired, and Gano Dunn, Past President of the Institute and Chairman of the National Research Council, Washington, D. C.

Mr. Dunn rehearsed Mr. Sperry's early life and pioneer work as an inventor. He was followed by the address of Mr. William L. Saunders, President of the United Engineering Society, Past President of the Institute of Mining and Metallurgical Engineers and Chairman of the Naval Consulting Board of the United States, who stated that as Active Chairman of the Board, he had been in intimate association with the medallist in his work of development of the gyrocompass and the application of the gyroscope to the stabilization of ships and airplanes. Without divulging any of the secret detail of mechanism and operation of the aerial torpedo, Mr. Saunders stated that the test of the torpedo was for a distance of about 35 miles but that it was organized to function at three times that distance. Rising to a predetermined height, it automatically leveled off for the flight, was automatically guided with a high degree of precision to any predetermined number of miles or fractions, then suddenly flew vertically downward to the object of its destruction. Each torpedo carried sufficient TNT to demolish a fortress or an ammunition dump, or, in the words of one of the admirals, "to blow a small town inside out." Mr. Saunders said that Mr. Sperry had had practical charge of this test work, in collaboration with a retired naval officer, Commander McCormick, requisitioned for this special duty. He stated also that Mr. Sperry was accredited with more than 400 patents among the most noted of which was the combination of electrical and mechanical elements in successful gyroscopic compasses and stabilizers for ships and airplanes. Eight years ago he announced his high intensity arc search light with a brightness 500 per cent greater than any previously made. This has become the standard searchlight for armies and navies in many countries.

Rear Admiral Fiske gave some descriptive detail of Mr. Sperry's inventive achievements,—the Sperry gyro-compass, the target-bearing and turret-control systems, the battle-tracer system, range-finding devices and his special work in developing the ship stabilizer.

The medallist acknowledged the honor conferred upon him as "overwhelming." He stated that since earliest boyhood there had been no doubt in his mind as to what he wanted to do although one of his earliest aspirations was to be a locomotive engineer; later the activities of Dr. William A. Anthony of Cornell University had given him higher ideals of attainment, however, when he commenced to understand the wonders of physics.

National Research Council

HIGHWAY BOARD'S SIXTH ANNUAL MEETING

The success of the first two Summary Bulletins already issued has led the Highway Research Board to establish the policy of an Annual Bulletin, designed to meet the demands of the engineer in such a manner as to make practical application of its data possible.

Requests for the complete report of the Proceedings of the Sixth Annual Meeting, which will be available about April 15, 1927, should be addressed to the Highway Research Board, National Research Council, Washington, D. C.

PERSONAL MENTION

A. E. Waller, Fellow of the Institute and actively helpful on its Marine Committee in the formulation of the new rules and marine standards, on Dec. 13th left his position as chief engineer of the Ward Leonard Electric Company to become managing director of the National Electrical Manufacturers Association. He had been chief engineer since 1918 and connected with the company since 1909. He has been active also in the affairs of the Elec. Mfgrs. Council and served two years as president of the Electric Power Club. Both of these organizations are included in the new association.

Leonard Kebler, also Fellow of the Institute, and president of the Ward Leonard Electric Company, will take over Mr. Waller's work as Chief Engineer of the Company for the present.

Elmer A. Smith, Member of the Institute, has been notified by the National President of the entire group of Academies of Sciences of the German Republic that he has been elected to membership in each academy as well as Special Honorary Advisor to represent the German Academies in the United States. Mr. Smith already is an Honorary Member, Fellow and Active Member of 107 Societies and academies throughout the world, among them the Academie d'Histoire in Paris and the National Institute of Switzerland.

John Herman Hunt, head of the Electrical Section, Research Division of the General Motors Corporation, Detroit, has been chosen president elect of the Society of Automotive Engineers. His installation will take place at the forthcoming annual meeting of the Society, January 13th. Mr. Hunt joined the Institute in 1907.

Obituary

George E. Luke, Research Engineer for the Westinghouse Electric & Manufacturing Company and Member of the Institute, was killed in an automobile accident on the morning of November 28th. Mr. Luke was an extremely active member of the Institute and although but 34 years old, had presented many papers before the various conventions as well as taking enthusiastic and able part in the discussion of many of others' authorship. He was a native of Seneca, Missouri, where he received his early schooling, later graduating from the University of Missouri with the degree of B. S. in Engineering. Mr. Luke also attended Princeton for a year and obtained his E. E. degree. In 1917 he entered the employ of the Westinghouse Electric & Manufacturing Co., with which he has remained ever since. He completed its graduate Student Course, including the engineering course and a six months' course in electrical design, after which he entered the Railway Motor Design Section. In 1918 he was located in New London, Conn., as the Westinghouse representative in the development of anti-submarine devices, and from 1919 to 1923, he was assigned to special experimental investigation for the Railway & Motor Engineering Departments. In 1924 he was elevated, to the position which he held at the time of his death, Section Engineer in charge of ventilation and insulation investigations of a research character. Mr. Luke joined the Institute in 1920 as an Associate and recently was transferred to grade of Member.

Edward Beach Ellicott, Fellow of the Institute since 1916, five years after he had joined it as an Associate, prominent engineer, and, at the time of his death, one of Chicago's most valued citizens, died October 26th following an operation from which he had not sufficient strength to recover. Col. Ellicott was president of the Board of Education of the City of Chicago, which position he had held for about a year and a half, taking it at a time when conditions were difficult but attacking the situation with good courage and bringing order out of chaos in a remarkably short time. Under his guidance large building programs were instituted and many activities for civic betterment had their inception.

Col. Ellicott was born March 28, 1866 at Hartland, New York, of a family of Americans since 1658; his grandfather was first Surveyor General of the United States. Col. Ellicott attended high school at Batavia, New York, and there also spent two years as a printer's apprentice. At the age of 19, he went to Missouri and put in a year at the printing trade. In 1886 he took up his professional work as engineer and electrician for the Salina Gas & Electric Co. The following year he removed to Concordia, Kansas, where, in 1888, he became superintendent of the Concordia Electric Light Co. In 1891, Col. Ellicott went to Chicago and engaged in work with the Western Electric Company as installation expert on lighting plants, from which position he rose to superintendent and then to superintendent of construction. In 1897, the City of Chicago elected him City Electrician, in which capacity he served for eight years. In 1904 he was made chief mechanical and electrical engineer of the Louisiana Purchase Exposition in St. Louis and the following year became chief electrical engineer of the Sanitary District of Chicago—a position he held until 1916, when he established his own consulting engineering practise. He served with distinction in the world war, first as Major, then as Lieutenant-Colonel and finally as full Colonel in the chemical warfare service, U. S. A., with supervision of the largest plant erected by America for the production of poisonous gas.

Col. Ellicott was also a member of The American Society of Mechanical Engineers and of the Western Society of Engineers, which he joined in 1900. He was president of the Construction Division Association, an organization of the engineer officers in the Construction Division of the United States Army. In conjunction with his professional career he is said to have exemplified the highest type of citizenship.

Francis M. Kenny, Associate of the Institute and recently engaged as chief engineer, Empresa de Telefonos, Maracaibo, Venezuela, S. A., died October 20, at Lancaster, Pa., whence he had returned in July for purposes of recuperation from a general breakdown. Mr. Kenny was a Canadian by birth, born at Greenville, Quebec, March 1866, where he received his education in the public and high schools. He also attended classes at the Toronto School of Sciences and was a student of the International Correspondence School. Three years of his early professional experience were spent with the Bell Telephone Company, Toronto, followed by three years more in their service at Philadelphia, Pa. He was then for 18 months with the Independent Telephone Company of Lancaster, Pa., and also spent a short time with the Western Electric Co. there. In 1900, he returned to the Bell Telephone Company, Canada, as installer and inspector, from which position he rose to wire chief, first at Philadelphia and then at Lancaster, again joining the Western Electric Company until his affiliation with the South American telephone interests in 1921 when he became chief engineer of the Compania Peruana de Telefonos Limitada, Lima, Peru.

Leo Lustig, Member of the Institute, located in Prague, C. S., died recently after several months' illness. Mr. Lustig was born in Bohemia, April 1880, and there received both his early high school and technical training, starting his professional career in the Construction Department of the Electricitats-Aktien-Gesellschaft, Kolben & Co., Prague, in 1903, as mechanical and electrical engineer. In 1905 he was transferred to the Estimating Department, where he remained for two years. Mr. Lustig then came to the United States and identified himself with the General Electric Company, Schenectady, N. Y., but shortly thereafter joined the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., in its Switch Department. He also spent some time in Cuba with Compania Central de Electricidad Y Traccion just prior to his return to Czechoslovakia. Mr. Lustig joined the Institute in 1911 as an Associate the year after his arrival in the United States, and was transferred to the grade of Member in 1919. He was a member of the Czechoslovakian Electrical Institute, Electrotechnicky' Svaz Cs. and some very interesting articles covering his studies of induction coils, oil-switches and current limiting reactors were published in the Journal *Electrotechnicky Obzor*.

Leo Basil Masten, power plant inspector for the New York Telephone Company, died at his home, Bloomfield, New Jersey, the latter part of October. Although Mr. Masten had joined the Institute only recently, in 1924, his professional work gave promise of high values, He was born at Union Hill, N. J., in 1897 and in January 1910, he identified himself with the Westinghouse Lamp Company as electrician. There he remained until 1913, when he became assistant electrical foreman for the Crucible Steel Co. of America. In 1917 he as made electrical foreman of Slocum, Avram & Slocum Engineering Company, Newark, N. J., and in 1918 started an electrical contracting business of his own. In September 1920 he received

an appointment to the Division Equipment Engineering Department of the New York Telephone Company, where he rose rapidly to the position which he held at the time of his death.

Joseph Harold Procter, Patent attorney for the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., died November 1, 1926. Mr. Procter joined the Institute in 1923. Born in Houston, Texas, June 20, 1890, he received his degree of B. S. from the A. & M. College of Texas in 1910, E. E. in 1913, and studied law from 1915 to 1918, when he was admitted to the Bar of Pennsylvania. The period of 1910 to 1912 was occupied as an engineering apprentice of Westinghouse Electric & Mfg. Co. in the test and design of transformers and induction motors. He then became Instructor of Electrical Engineering in the A. & M. College of Texas, taking his present position of Patent Attorney for Westinghouse Company in 1913, where he specialized in electrical inventions for company developments.

Charles S. Cook, Associate of the Institute and vice-president and treasurer of the Kaestner & Hecht Elevator Company, died in Pittsburgh, November 15. Mr. Cook was formerly associated with the Westinghouse Electric & Mfg. Co. and the Duquesne Light Company and was a widely known and outstanding figure in electrical manufacturing and business circles, having been identified with the industry since 1887. He was conspicuous in electric light and power field, street and urban railway development and electrification of steam railways. Mr. Cook was a native of Amherst, Mass. (1863) and a graduate of Worcester Polytechnic Institute. In 1887 he entered the employ of the Westinghouse Company and soon after was advanced to erecting engineer. Later he was sent to the Chicago office, where he received the appointment of sales engineer. In 1892 he laid out and sold the first long distance transmission system installed in the United States. This was at Pomona and San Bernadino, Calif.. where a 28-mi., 10,000-volt system was installed. That same year, Mr. Cook planned the power system for the World's Columbian Exposition at Chicago. In 1895 he was transferred to Pittsburgh to take up the application of electrical apparatus in steel mills, and the subsequent growth of this development of the application of electric power to mills is said to be largely the result of Mr. Cook's personal work in the field.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is adminstered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES NOVEMBER 1-30, 1926

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

AIRMEN AND AIRCRAFT.

By Henry H. Arnold. N. Y., Ronald Press Co., 1926. (Ronald Aeronautic library). 216 pp., illus., diagrs., 9 x 6 in., cloth. $3.50.

A general description book, written in simple, non-technical language. The author describes the various kinds of air-craft and their uses, explains the training of aviators in the Army and private schools, gives some notes on famous flights and noted fliers and discusses the future of aviation.

ATMOSPHERIC NITROGEN INDUSTRY.

By Bruno Waeser. Phila., Blakiston's Son & Co., 1926. 2 v., illus., diagrs., tables, 10 x 6 in., cloth. $10.00. 2 vols.

Dr. Waeser's extensive treatise on the extraction of nitrogen from the air has now been made available to those who could not read the German edition. In its comprehensiveness it is superior to any treatise hitherto available in the English language.

The first volume is devoted to history and economics. The history of the nitrogen industry prior to direct fixation is outlined, after which the development of the atmospheric industry is set forth in each country, with considerable technical and economic detail. In the second volume the various technical processes, by arc, by catalysis, etc., are described. Extensive bibliographies and lists of patents are included.

BOOK OF THE AEROPLANE.

By Capt. J. Laurence Pritchard. N. Y. & Lond., Longmans., Green & Co., 1926. 255 pp., illus., 8 x 5 in., cloth. $2.75.

A good book for the general reader who wishes to be informed on the past and present of aviation. Mr Pritchard discusses such topics as the early history, famous flights, races, the various types of airplanes and seaplanes, airplane engines, how airplanes fly, commercial and military uses and future development. The style is interesting and technicalities of slight interest to the general public are omitted.

CHEMISCHE TECHNOLOGIE DER LEICHTMETALLE UND IHRER LEGIERUNGEN.

By Friederich Regelsberger. Lpz., Otto Spamer, 1926. 385 pp., illus., ports., 10 x 7 in., paper. 26,—r. m. Bound, 29,-r. m.

Dr. Regelsberger's monograph is a convenient summary of our knowledge of the light metals, based on a thorough expert examination of the literature to the end of the year 1924. He discusses their occurrence in nature, history, physical and chemical properties, alloys and compounds, metallurgy, preparation for use, and their uses. A chapter is given to statistics and trade conditions. Lists of the important patents, European and American, are included. The metals included are lithium, potassium, sodium, rubidium, calcium, megnesium, caesium, beryllium, strontium, aluminium and barium.

CHEMISTRY IN THE WORLD'S WORK.

By Harrison E. Howe. N. Y., D. Van Nostrand Co., 1926. 244 pp., illus., 9 x 6 in., cloth. $3.00.

Dr. Howe has written an interesting account of the part that chemistry has played in bringing the world to the present level of civilization. He indicates in broad outline what the chemist has contributed to such important topics as food, clothing, structural materials, health and communication, together with others

of less vital importance. The book is primarily for those not technically trained but nevertheless will interest others whose experience does not cover the whole field of human effort.

COLLOID AND CAPILLARY CHEMISTRY.

By Herbert Freundlich. N. Y., E. P. Dutton & Co., [1926.] 883 pp., illus., diagrs., tables, 10 x 6 in., cloth. $14.00.

The first part of this book deals with the physico-chemical foundations of colloid chemistry, that is to say, with capillary chemistry or the chemistry of interfaces, the formation and interconversion of phases, and molecular motion. The second part is devoted to the properties and behavior of colloidally disperse systems or, in other words, to colloid chemistry. The subject is treated exhaustively, and references to the literature are given profusely, so that the work is a valuable summary of our knowledge of the subject.

DIE DAMPFKESSEL, v. 1; Kesselsysteme und Feuerungen.

By Friedrich Barth. Berlin u. Leipzig. Walter de Gruyter & Co., 1926. 142 pp., illus., diagrs., 6 x 4 in., cloth. 1,50 r. m.

A brief introduction to the subject of steam generation and the steam boiler, based on scientific principles, but couched in non-technical language. This volume discusses the general principles, the theory of combustion, methods of firing, heat conduction and heat losses, systems of boilers and steam economy.

THE DIVINING-ROD.

By Sir William Barrett and Theodore Besterman. Lond., Methuen & Co., 1926. 336 pp., illus., 9 x 6 in., cloth. 18s.

This is a very interesting book on the art of dowsing. The authors have examined the literature, have collected and examined critically a substantial number of contemporary cases and have carried out experiments designed to test the claims made on behalf of "water divining." They trace the belief back to antiquity, describe the activities of some of the notable dowsers of today and discuss the mechanism and the rationale of dowsing. The book has numerous illustrations and a good bibliography.

As a result of their investigation, the authors conclude that dowsing is not mere superstition. Certain individuals, they believe, have a subconscious supernormal faculty that enables them to discover the location of underground water, ores, metals and other substances.

DIE EBENE UEKTORRECHNUNG UND IHRE ANWENDUNGEN IN DER WECHSELSTROMTECHNIK, v. 1; Grundlagen.

By Heinrich Kafka. Lpz. u. Ber., B. G. Teubner, 1926. 132 pp., diagrs., tables, 8 x 5 in., paper. 7,60 r. m.

This textbook is intended to familiarize the student with the applications of vector analysis to alternating-current problems. The author gives a general introduction to vector analysis, followed by a presentation to the theoretical electrical principles necessary to the use of vectors. He then shows how the method is applied to the solution of engineering problems. The discussion is limited to stationary phenomena.

EDISON, THE MAN AND HIS WORK.

By George S. Bryan. Lond. & N. Y., Alfred A. Knopf, 1926. 350 pp., illus., ports., 9 x 6 in., cloth. $4.00.

It has been many years since any extensive account of Edison's life and inventions has been published, and much of what has been written about him is more or less inaccessible to the general reader. This biography brings the story of Edison down to date, within moderate compass, telling the main incidents of his career in clear, readable narrative.

The book is based on considerable personal inquiry and examination of the literature. The author has endeavoured to present the man and at the same time to explain his work in non-technical language, with sufficient fulness to satisfy the curiosity of the average reader. The result is a well balanced book.

ELECTRIC CIRCUIT THEORY AND THE OPERATIONAL CALCULUS.

By John R. Carson. N. Y., McGraw-Hill Book Co., 1926. 197 pp., 9 x 6 in., cloth. $3.00.

This book may be regarded, according to the author, either as an exposition and development of the operational calculus, with applications to the theory of the electric circuit, or as a contribution to the advanced theory of the circuit. The first portion of the book gives a fairly complete exposition and critique of the Heaviside operational calculus. This calculus the author deduces from an integral equation by a simpler method than that used by Heaviside. The second part deals with advanced problems of electric circuit theory, especially with the theory of the propagation of current and voltage in electrical transmission systems.

ELECTRIC TRANSIENTS.

By Carl Edward Magnusson. 2d edition. N. Y. McGraw-Hill Book Co., 1926. 237 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

An introductory textbook intended to give clear concepts of electric transient phenomena and their application to quantitative problems. It represents the course given by the author at the University of Washington. The second edition is essentially a new book, as all the illustrations of oscillograms are new, every chapter has been revised and one chapter has been added.

ELEKTRISCHE ZUNDUNG, LICHT UND ANLASSER DER KRAFTFAHRZEUGE.

By E. Seiler. Halle (Saale), Wilhelm Knapp, 1926. 169 pp., illus., 10 x 7 in., paper. 7,60 r. m.

An extensive discussion of the electrical equipment of the automobile. Treats of ignition, starting, signaling and lighting, describing the theory and construction of the apparatus used for these purposes. The book is intended primarily for repairers and owners, but will also interest manufacturers.

DIE ELEKTRISCHEN MASCHINEN.

By M. Liwschitz. Lpz. & Ber., B. G. Teubner, 1926. 336 pp., illus., diagrs., 9 x 6 in., boards. 14, r. m.

An elementary textbook intended to give the fundamentals for further study of the theory of electrical machinery and to show the relation between the phenomena in electrical machinery and the laws of nature. To this end attention is concentrated on the more important phenomena and secondary phenomena are omitted. The theory of the various kinds of machines is developed to the extent necessary for the design of the machine and the outline of the winding. The author is chief engineer of the Siemens-Schuckert works.

ELEMENTARY HEAT AND HEAT ENGINES.

By F. G. R. Wilkins. Lond. & N. Y., Oxford Univ., Press, 1926. 312 pp., illus., diagrs., tables, 8 x 5 in., cloth. $2.50. (Gift of American Branch).

Suited to the needs of students in trade schools and technical institutes and of those interested in allied branches of science who wish a general insight into the principles underlying the operation of heat engines.

ELEMENTS OF AEROFOIL AND AIRSCREW THEORY.

By H. Glauert. Cambridge University Press, 1926. 228 pp., diagrs., tables, 9 x 6 in., cloth. $5.60. (Gift of Macmillan Co., N. Y.).

The aim of aerofoil theory is to explain and to predict the force experienced by an aerofoil; and as the airscrew blades are aerofoils, the problem of the airscrew is essentially a part of the theory. Although the theory is at present incomplete, certain portions have been developed to a usable point, and from the fundamental principles a satisfactory theory of the propulsive airscrew has been developed.

The aim of the present book is to give an account of aerofoil and airscrew theory in a form suitable for those who have no previous knowledge of hydrodynamics. A brief introduction to the aspects of hydrodynamics which are required for the development of aerofoil theory is given, followed by chapters on the lift of an aerofoil, the effect of viscosity, aerofoil theory and airscrew theory.

ELEMENTS OF INDUSTRIAL CHEMISTRY.

By Allen Rogers. N. Y., D. Van Nostrand Co., 1926. 680 pp., illus., diagrs., 9 x 6 in., cloth. $4.50.

An abridgment of the large "Manual of Industrial Chemistry" issued under the editorship of Mr. Rogers. The smaller work, which is intended for teachers who wish a briefer textbook, treats each subject in a general manner only, eliminating detail in order that fundamental principles shall stand forth clearly. The treatment is essentially descriptive. The new edition, which is based on recent revisions of the parent work, has been brought up to date by omissions and new matter.

ELEMENTS OF MOTOR VEHICLE DESIGN.

By C. T. B. Donkin. Lond. & N. Y., Oxford University Press., 1926. 277 pp., diagrs., tables, 9 x 6 in., cloth. $4.25. (Gift of Oxford Univ. Press. American Branch).

A textbook on automobile design which demands of the reader an elementary knowledge of mechanics and practical mathematics and a general acquaintance with the mechanism of a

motor car. On this basis, it develops the subject from first principles and teaches the student to apply the theory to practical design. The book covers the problems that are encountered in the drawing office and the factory.

ENGINEERING METALLURGY; A Textbook for Users of Metals.

By Bradley Stoughton and Allison Butts. N. Y., McGraw-Hill Book Co., 1926. (Metallurgical Texts). 441 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

This textbook covers a broad field in a concise fashion. Starting with an account of the physical and mechanical properties of metals, the reader is introduced to the current methods of examining and testing them. The occurrence of metals in nature and the general methods of obtaining and refining them are then described. Chapters follow on electrometallurgy, on the mechanical working of metals and on alloys, after which the properties and uses of the various metals, and the processes for producing and refining them are given individual treatment. The remainder of the book discusses corrosion, fuels and combustion, slags, fluxes, refractories, pyrometry, and heat transfer and heat losses in furnaces.

The book is a good introduction to the subject for those who intend to specialize in it, but its primary purpose is the instruction of those who, as mechanical or civil engineers, will be users of metals. The subject is therefore treated from the viewpoint of utilization, and emphasis is laid on the relation of the structures and properties of metals to their uses and the effects of working, impurities and processes of production on their properties.

ENGINEERING PROBLEMS.

By William G. Raymond, Sherman M. Woodward and Irving H. Prageman. N. Y., McGraw-Hill Book Co., 1926. 47 pp., diagrs., tables, 9 x 6 in., cloth. $1.00.

A text for a review and orientation course for sophomore students, used in the University of Iowa. It is intended to review the more important fundamental facts of physics and chemistry, to illustrate and cultivate the application of physics and chemistry to every-day problems showing the sort of work comprehended in actual engineering and to illustrate the method of attack upon practical problems usually adopted by the engineer.

ERDDRUCK, ERDWIDERSTAND UND TRAGFAHIGKEIT DES BAUGRUNDES.

By H. Krey. Berlin, Wilhelm Ernst & Sohn, 1926. 296 pp., illus., diagrs., tables, 10 x 7 in., paper. 21,60 mk.

A treatise on earth pressures, earth resistance and supporting power, designed primarily to assist practising engineers in the solution of the problems that arise in the course of their work. The author sets forth, without using complicated mathematics, the theory and basic principles for calculating earth pressures, and describes practical methods of calculation. Chapters are devoted to earth resistance, the bearing-power of piles and their resistance to withdrawal, the effects of cohesion, and the earth pressure on arches and on high dams. A series of tables of earth pressures is given, by which earth pressures may be calculated rapidly with sufficient accuracy for ordinary construction. A bibliography is given.

FORTSCHRITTE DER ABWASSERREINIGUNG.

By Karl Imhoff. 2d edition. Berlin, Carl Heymanns Verlag, 1926. 136 pp., illus., 9 x 6 in., boards. 5,-r. m.

Intended to give those familiar with the subject a concise survey of developments in the theory and practise of sewage purification since 1914. Included are a bibliography of the writings of Dr. Imhoff and his associates and of the literature upon which this book is based.

GASOLINE AUTOMOBILES.

By James A. Moyer. 2d edition. N. Y., McGraw-Hill Book Co., 1926. 352 pp., illus., 8 x 5 in., cloth. $2.50.

Aims to present the essential principles of automobile construction and operation in a form that will appeal to the owner and driver without technical education. The author describes the details of the automobile, explaining the purpose of each and showing the various designs in common use. The language is simple and clear.

In the new edition various emendations and expansions have been made, to keep the book abreast of current practise.

GEARS AND GEAR CUTTING, previously "Toothed Gearing."

By Joseph Horner; revised ... by Philip Gates. Lond., Crosby Lockwood & Son, 1926. 139 pp., illus., diagrs., tables, 7 x 5 in., cloth. 5s.

This modernization of Horner's "Toothed Gearing" has been thoroughly carried out. The result is a practical little manual on spur, bevel, worm, helical and spiral gears, which describes clearly the design, cutting and testing of these standard forms. While much of the original text is retained, much that is no longer useful has been omitted, and a considerable amount of new material has been added.

GLEICHRICHTER.

By Josef Just., Berlin & Leipzig, Walter de Gruyter & Co., 1926. 136 pp., illus., diagrs., 6 x 4 in., cloth. 1,50 r. m.

A concise, up to date description of the varieties of electric-current rectifiers, in a small, inexpensive book. While some attention is given to mechanical rectifiers, the major part of the book is devoted to the various forms of electrolytic and mercury-arc rectifiers. A short chapter on electrical dust and smoke removal is included.

HOUSE HEATING.

By Margaret Fishenden. Lond., H. F. & G. Witherby, 1925. 296 pp., illus., diagrs., 10 x 8 in., cloth. 25s.

A description of current practice in domestic heating in Great Britain. Dr. Fishenden discusses fuels, grates for living-rooms, kitchen ranges, the use of gas and electricity for heating and cooking, and central heating. Her book describes the apparatus used in England and brings together in convenient form much information on the subject.

HYDROGRAPHIC OFFICE.

By Gustavus A. Weber. Balt., Johns Hopkins Press, 1926. (Institute for Government Research Service Monographs no. 42) 112 pp., 9 x 6 in., cloth. $1.00.

A descriptive study of the Hydrographic Office. Traces its history, explains its functions, describes its organization and plant for fulfilling them, and gives information on the laws that govern it and on its cost.

HYDROUS OXIDES.

By Harry Boyer Weiser. N. Y., McGraw-Hill Book Co., 1926. (International Chemical series). 452 pp., tables, 8 x 6 in., cloth. $5.00.

This volume, the author states, is the first endeavor to correlate systematically and summarize critically the numerous scattered facts available upon colloidal properties of hydrous oxides. The book opens with an introductory chapter on the structure, preparation and properties of jellies and gelatinous precipitates. Chapters are then devoted to the typical oxides of iron, chronium, aluminum, copper and the other metals, after which are chapters on such important industrial applications of these oxides as tanning, mordants, water purification, cement and soils.

INSTALLATIONS ELECTRIQUES A HAUTE ET BASSE TENSION.

By A. Mauduit. Paris, Dunod, 1926. 2v., illus., diagrs., 10 x 7 in., paper. 150,-fr. 2 v.

This work is intended to supplement Professor Mauduit's previous book on electrical machinery, which dealt with the theory and construction of dynamos and motors. It is devoted to the industrial uses of these machines and is an encyclopedic review of the production, transportation, distribution and use of electrical power. The work covers a wide field, uses many diagrams and avoids unnecessary mathematical complexities. It aims to give the electrical engineer a convenient work of reference, practical in character, without undue prolixity.

KUPFER.

By U. S. Bureau of Standards. Translated by P. Siebe. Issued by Deutscher Gesellschaft für Metallkunde. Berlin, V. D. I. Verlag, 1926. 120 pp., illus., diagrs., tables, 8 x 6 in. paper. 5,60 r. m.

A translation of Circular No. 73 of the U. S. Bureau of Standards.

MAGNETISM AND ATOMIC STRUCTURE.

By Edmund C. Stoner. N. Y., E. P. Dutton & Co., 1926. 371 pp., diagrs., 9 x 6 in., cloth. $5.00.

Intended as a supplement to ordinary works on magnetism, this books gives an account of magnetic phenomena, and of the attempts made to interpret them in terms of the quantum theory. The treatment is semi-historical. The author has attempted to make the book complete within the selected range. His method is to give reasonably complete outlines of representative researches and to base discussions upon these.

Mathematical Theory of Electricity and Magnetism.

By J. H. Jeans. 5th edition. Cambridge University Press, 1925. 652 pp., 10 x 7 in., cloth. 21s. (Gift of Macmillan Co., N. Y.)

Dr. Jeans's treatise is too well known to students of electromagnetic theory to need extended review. It covers about the ground covered by Maxwell's famous treatise but does not require so thorough a mathematical equipment, being intended more especially for the student.

In this edition the author has introduced such changes as the new theories of relativity and quanta demand and has added a chapter on the electrical structure of matter which will introduce the reader to the theory of quanta.

Metallographic Researches.

By Carl Benedicks. N. Y., McGraw-Hill Book Co., 1926. 307 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

Contents: Some points of view on the kinetic constitution of solid matter.—Homogeneous thermoelectric and electrothermal effects.—Hardness in general and the hardening of carbon steel, high-speed steel and other alloys.—Meteoric iron and invar.—Some improvements in high-power microscopy.—Microchemical etching method for metallography.—First discoverer of the critical point Ac in Steel.—Some fundamental factors for obtaining sharp thermal curves.—Determination of the specific gravity of molten iron.—Rational ingot section for hard-rolled material.—Action of hot wall; a factor of fundamental influence on the rapid corrosion of water tubes and related to the segregation in hot metals.—Index.

Part of the contents of this volume is made up of lectures delivered before the Division of Metals of the American Institute of Mining and Metallurgical Engineers and other organizations. As the table of contents indicates. the text discusses a somewhat heterogeneous collection of topics which interest the metallographist and metallurgist, the subjects being those which have recently been investigated at the Institute of Metallography, Stockholm, under the direction of the author.

Metallurgy of the Common Metals.

By Leonard S. Austin. 6th edition. N. Y., John Wiley & Sons, 1926. 658 pp., illus., diagrs., 9 x 6 in., cloth. $7.00.

Austin's metallurgy is intended especially for the student of mining and aims to give him a general outline of the metallurgy of the metals with which he will practice, as a preliminary to the detailed study of individual metals. The book opens with a section on the treatment of ores, fuels, refractories, sampling, crushing, furnaces, roasting and concentration. The concentration, reduction and refining of the individual metals are then considered. Special attention is given to underlying principles but details of processes and the design and operation of plants are also considered.

Motorship Yearbook.

4th edition. N. Y., Motorship, 1926. 208 pp., illus., 10 x 8 in., fabrikoid. $3.00.

The yearbook contains a number of interesting articles on modern progress in motorship construction and equipment and on the installation and operation of their machinery. Other useful information includes tables of bunkering stations, radio beacons and motorships. The last table includes data on about nine hundred vessels of over three hundred horse-power, arranged in chronological order.

New Heat Theorem.

By W. Nernst. N. Y., E. P. Dutton & Co., [1926.] 281 pp., 9 x 6 in., cloth. $4.00.

Nernst's Heat Theorem asserts that the temperature coefficients of the free and total energy in any system decrease to indefinitely small values as absolute zero of temperature is approached. This hypothesis is offered as a third law of thermodynamics and, while it can not be directly verified, it has been found to agree satisfactorily with experiment. It enables the maximum work of a system to be calculated from heat measurements alone.

In the present book Dr. Nernst gives a historical account of the theorem and describes the researches undertaken by him and his fellow-workers to test its validity and to discover its applications.

Notes on the Induction Motor.

By H. E. Dance. Lond. & N. Y., Oxford University Press, 1926. 152 pp., diagrs., 8 x 5 in., cloth. $2.00. (Gift of American Branch).

This book is intended for students of engineering who do not wish to study the induction motor from the viewpoint of the designer, yet who wish a thorough working knowledge of it. It aims to present compactly a complete approximate theory of the motor, with notes on starting, speed control and power factor. Those details that are of interest to students of design alone have been omitted.

Personnel Administration, Its Principles and Practice.

By Ordway Tead and Henry C. Metcalf. 2d edition. N. Y., McGraw-Hill Book Co., 1926. 543 pp., 9 x 6 in., cloth. $5.00.

Aims to set forth the principles and the best prevailing practice in the field of the administration of human relations in industry. This field includes the various efforts; health and safety, training, personnel research, services and joint relations; that are usually grouped as personnel management, and also a consideration of associations of employers and their dealings with national organizations of workmen.

The new edition has been revised throughout, to meet the advances that have occurred during the past six years.

Power Plant Testing.

By James Ambrose Moyer. 3rd edition, enl. N. Y., McGraw-Hill Book Co., 1926. 609 pp., illus., diagrs., tables. 9 x 6 in., cloth. $5.00.

Describes in some detail generally approved methods of testing these machines and also describes the apparatus used and the calibrations required for accurate testing. While intended primarily for students in laboratory courses, the book also aims to give engineers, who are not thoroughly familiar with up to date methods, a survey of those now in use.

The new edition conforms to the latest codes adopted by the various societies and committees and has been revised throughout.

Principles of Refrigeration.

By William H. Motz. Chicago, Nickerson & Collins Co., 1926. 657 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

The substance of this book has been used for three years by the National Association of Practical Refrigerating Engineers as a course of lectures to its chapters and for home study. It aims to give, without using higher mathematics, a comprehensive grounding in the fundamental principles of refrigeration and a description of their application to ice-making and refrigeration. It describes the construction of ice and refrigerating plants and the operation and care of the apparatus and gives much practical information of value to those employed in the industry.

Schleudergeblase, Berechnung und Konstruktion.

By Hans Rudolf Karg. München u. Berlin, R. Oldenbourg, 1926. 128 pp., illus., diagrs., 10 x 7 in., paper. 7, 50 r. m.

The scanty literature of centrifugal fans is largely descriptive and empirical, and there is a lack of books which provide a student with a systematic exposition of the scientific principles that underlie these machines, and of the application of these principles in construction.

This handbook aims to present the physical laws of ventilating fans, so far as they are necessary for designing centrifugal fans, and to describe the design and construction of the latter in sizes up to 60 inches blade diameter and to the highest pressures attainable.

Shop Hints on Locomotive Valve Setting.

By Jack Britton. 2d edition. N. Y., Simmons-Boardman Publ. Co., 1926. 350 pp., illus., diagrs., 8 x 5 in., fabrikoid. $3.00.

This book explains the theory of the locomotive valve gears in use, describes the details of their construction, and tells how to set them. The author is a practical valve setter, and the book is planned for use in erecting and repair shops.

Thermodynamics for Students of Chemistry.

By C. N. Hinshelwood. N. Y., E. P. Dutton & Co., 1926. 185 pp., 8 x 5 in., cloth. $1.80.

The basis of this book is a course of lectures, given at Trinity College, Oxford. The author has attempted to make the fundamental ideas of thermodynamics as clear as possible and particularly to explain the methods by which the abstract general laws are brought to bear upon the actual problems of physics and chemistry.

Transmission Line Theory and Some Related Topics.

By William Suddards Franklin and Frederick Emmons Terman. Lancaster, Pa., Franklin & Charles; Lond., Constable & Co., 1926. 312 pp., diagrs., 9 x 6 in., cloth. $4.00.

This treatise stresses the fundamental mathematical aspects of the subject, makes use of physical conceptions wherever possible, and is written with the needs of the engineer in mind. Special features, according to the authors, are: a unique discussion of

transmission line transients; the development of the hyperbolic theory of the alternating current line by means of the concept of the decaying wave-train; a full discussion of the circle diagram of the transmission line; a simple exposition of wave-filters; the discussion of Fourier's series; and a simple discussion of wave distortion and the effects of line loading.

The Use of Power in Colliery Working.

By John Kirsopp. Lond., H. F. & G. Witherby, 1926. 579 pp., illus., diagrs., tables, 10 x 6 in., cloth. 40 s.

A discussion of the power equipment of collieries, based on conditions in Great Britain. Starting with the steam power plant, the book treats of the plants for generating electricity and compressing air, after which attention is paid to the use of power in hoisting, pumping and hauling. A chapter is devoted to wire ropes, and electric pumps are given special attention. In appendixes there is much information on fluctuations in the cost of materials and of wages in Great Britain.

The subjects are treated in detail, and much space is given to descriptions of various designs of machinery. Special attention is paid to costs and many cost data are found in the text.

Ventilation of Mines.

By Walter S. Weeks. N. Y., McGraw-Hill Book Co., 1926. 228 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.00.

The author discusses the physical, physiological and engineering problems that need consideration in designing systems of ventilation for mines. He aims to present the principles and experimental data that are necessary for the design of adequate systems for mines of any type.

Wage Scales and Job Evaluation.

By Merrill R. Lott. N. Y., Ronald Press Co., 1926. 161 pp., 9 x 6 in., cloth. $5.00.

The author has devised a plan for developing a system of wage scales which will adjust equitably the wages paid by a concern to workers in different crafts and to workers of different degrees of skill in the same craft. The book presents all the information necessary to apply the method in any manufactory. The method has been used successfully by a manufacturing concern.

Warmewirtschaft im Eisenhuttenwesen.

By Max Schlipköter. Dresden u. Leipzig, Theodor Steinkopff 1926. (Wärmelehre und Wärmewirtschaft. . . bd. 3). 119 pp., illus., diagrs., tables, 9 x 6 in., paper. 7-r. m.

This small book aims to give the manufacturer of iron and steel a concise, specific account of the ways in which modern findings in heat economy may be applied to his business. The latest theories of heat, and the devices and methods that have survived practical tests are described. The book covers heat economy at the blast-furnace and in the steelworks, the rolling-mill and the foundry, the production of power and the heating of the plant.

Welding Encyclopedia.

Compiled and edited by L. B. Mackenzie and H. S. Card. Fifth edition. Chicago, Welding Engineer Publishing Co., 1926. 479 pp., illus., 9 x 6 in., fabrikoid. $5.00.

The encyclopedic section, which comprises about one-third of the book, contains information on many processes, materials, methods of welding special articles, etc., arranged alphabetically. This is followed by systematic accounts of the equipment and methods for oxy-acetylene, electric arc, electric resistance and thermit welding, and of the application of these processes to cutting and to the welding of boilers, pipe, tanks and rail joints. A course of training for welders is outlined, which is followed by the rules and regulations for welding prescribed by various governmental and industrial agencies, charts showing how articles should be prepared for welding, and various useful tables. A catalog section concludes the book.

Intrusionstektonik U. Wandertektonik Im Variszischen Grundgebirge.

By Franz Ed. Suess. Berlin, Gebrüder Borntraeger, 1926. 268 pp., maps, 10 x 7 in., paper. 21,-r. m.

Dr. Suess has for many years devoted himself to the study of the earth movements in the vanished mountain ranges of central Europe. The results of his extended observations in the field are now presented in this volume, together with the conclusions that he has drawn from them. His investigations make no pretension to conclusiveness but will nevertheless interest students of metamorphism generally.

Theory of Vibrating Systems and Sound.

By Irving B. Crandall. N. Y., D. Van Nostrand Co., 1926. 272 pp., diagrs., 9 x 6 in., cloth. $5.00.

Contents: Simple vibrating systems.—General theory of vibrating systems; resonators and filters.—Propagation of sound.—Radiation and transmission problems.—Acoustics of closed spaces; absorption, reflection and reverberation.—Appendices: Resistance coefficients; Recent developments in applied acoustics.—Indexes.

The volume is based on studies in the Bell Telephone Laboratories, and the material was first presented in an "out-of-hours" course to the other members of the technical staff at that place. It aims to present the theory of sound and its recent applications in such a way as to interest the student of physics who has given a certain amount of attention to analytical mechanics and who wishes to bring his knowledge of sound into balance with his studies in other branches of the science of mechanics. It is intended to supplement, rather than replace, the accepted treatises on sound.

Radiotechnik, v. 2; Wellentelephonie.

By Werner Bloch. Ber. u. Lpz., Walter de Gruyter & Co., 1926. 124 pp., illus., diagrs., 6 x 4 in., cloth. 1,50 r. m.

A very brief account of the theory of radio-telephony and of the practical methods and the apparatus in use. A long chapter is devoted to "wired wireless" telephony.

Emile Berliner, Maker of the Microphone.

By Frederic William Wile. Indianapolis, Ind., Bobbs-Merrill Co., 1926. 353 pp., illus., port., 9 x 6 in., cloth. $4.00.

An interesting account of Mr. Berliner's life, which lays particular stress on his contributions to the development of the telephone and the talking machine.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify the Institute Headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage, and clerical work.

1.—J. B. Adams, 4435 Ravenswood Ave., Chicago, Ill.
2.—H. C. Billington, Washington Mills, Lawrence, Mass.
3.—E. J. Boynton, 78 Johnson Park, Buffalo, N. Y.
4.—H. P. Buckley, 160 S. Portland Ave., Brooklyn, N. Y.
5.—W. H. Costello, 771 51st St., Milwaukee, Wis.
6.—E. Y. Danner, Kapowsin, Wash.
7.—A. Davidson, Kittrell College, Kittrell, N. C.
8.—J. B. Dyer, 135 Wesley Ave., Ferguson, Mo.
9.—A. S. Eisenmann, 663 State St., Springfield, Mass.
10.—E. C. Ellwanger, 40 Washington Ave., Schenectady, N. Y.
11.—S. Freeman, 561 W. 163rd St., New York, N. Y.
12.—G. E. Kerr, 1256 10th Ave., W., Vancouver, B. C., Can.
13.—D. F. MacDonald, 171 E. 94th St., New York, N. Y.
14.—C. R. McGahey, 705 Bona-Allen Bldg., Atlanta, Ga.
15.—H. Northrop, Central Jagueyal, Prov. Camaguey, Cuba.
16.—O. M. Olsen, 3351 W. Congress St., Chicago, Ill.
17.—H. L. Parker, 2645 Van Ness Ave., San Francisco, Calif.
18.—A. M. Perry, 7732 N. Paulina St., Chicago, Ill.
19.—C. B. Raymond, 830 N. E. 39th St., Portland, Ore.
20.—C. F. Rohde, 1908 New Kirk Ave., Brooklyn, N. Y.
21.—G. K. Selden, Southern Bell Tel. & Tel. Co., Jacksonville, Fla.
22.—J. B. Shinkle, 120 Chestnut St., Takhoma Park, Washington, D. C.
23.—J. R. Troy, Glen Head, L. I., N. Y.
24.—J. Veralli, 1998 Madison Ave., New York, N. Y.
25.—F. M. Williams, 1420 Nostrand Ave., Brooklyn, N. Y.
26.—C. L. Youngs, Bd. of Water & Elec. Lt. Comm., Lansing, Mich.

A. I. E. E. Student Activities

The electrical engineering students in the colleges today constitute the group from which will be built the foundation of the Institute of the future. In recognition of this fact, the Board of Directors of the Institute, many years ago, authorized the establishment of Student Branches composed of electrical engineering students in the various colleges, for the purpose of providing an instrumentality for the development of the latent ability of students in carrying on organization work by actual participation in meetings and other activities.

During the past year the Directors have instituted another step toward the further development of Student activities by authorizing the appointment of a Counselor in each Branch, who is in each instance a member of the faculty in which the Branch is located and also a member of the Institute.

A Committee on Student Activities has also been authorized in each of the Geographical Districts, composed of the Counselors within the District together with the Vice-President and Secretary of the District. The principal function of these District committees will be to coordinate Student activities in their localities.

At a recent meeting of the Publication Committee of the Institute, it was decided to inaugurate a separate department in the monthly JOURNAL, to be published under the above heading and in which will be included brief references to the activities of the Student Branches, the Counselors, the District committees and any other matters of interest within the field indicated. It is believed that this department will result in increased interest in, and activity by, the Students, and it is hoped that it will be possible to include in this department of the JOURNAL from time to time, some of the worthier papers presented by the Students, at various meetings, as for example, the prize-winning Student papers in the various Districts.

SANTA CLARA, AKRON AND PRINCETON ORGANIZE NEW STUDENT BRANCHES

Three new Student Branches have recently been organized at the University of Santa Clara (Cal.), the Municipal University of Akron (Ohio), and Princeton University respectively. The addition of these Branches increases the total number to 93.

The Santa Clara Branch was authorized on October 15, and since that time has been organized and the following officers and members of the Executive Committee have been elected: Chairman, F. Whitwam; Secretary-Treasurer, Wm. P. Fisher; Vice-Chairman, R. P. O'Brien; N. K. Delaney, E. Newton and J. L. Quinn. D. W. Griswold is Counselor for the Branch.

The Branch at the University of Akron, authorized October 15, held its first meeting on November 10 and the following officers were elected; Chairman, Lee J. Shaffer; Secretary, S. K. Worthen; Treasurer, K. E. Burgan; Chairman of Papers Committee, R. R. Grenwald; Chairman of Membership Committee, R. C. Tryon.

The Princeton Branch, which was authorized August 10, held an organization meeting on December 7 and elected an executive committee consisting of J. McN. Myers, Local Secretary; A. F. Lukens, graduate member, J. Reine, Senior-Class member, R. W. McGregor, Jr., Junior-Class member, and Prof. Malcolm MacLaren, Counselor. The Branch decided to have monthly meetings at which two papers will be read by members and discussed.

PENN STATE BRANCH HOLDS ELECTRICAL SHOW

An Electrical Show was held by the Student Branch at Pennsylvania State College on Alumni Day, October 23. The displays consisted of practical exhibits of household appliances, lighting, etc., and a number of interesting "trick" displays.

Among the more serious exhibits was a display of household appliances connected to a wattmeter calibrated to read the cost of energy in cents per hour. A display of colored lights banked with ferns and chrysanthemums was a great attraction. An orthophonic Victrola, equipped with audion tubes for amplification, alternated with a student orchestra to provide music during the show.

The "trick" exhibits included a wireless light, a magnetic egg, gas electric lamps, a tin-can lid motor, an illuminated soap-bubble fountain, an arc lamp with glass electrodes, electric scales and stunts with a Tesla coil.

BRANCH MEETINGS

Alabama Polytechnic Institute

Motion pictures, entitled "The Queen of the Waves" and "Big D," were shown. November 17. Attendance 41.

Oil-Electric Locomotives, by S. L. Hancock; *Summer Work*, by Fox Cardwell, Jr.; *Care and Operation of Watthour Meters*, by G. N. Lagrone. December 1. Attendance 39.

Business Meeting. The following officers were elected: Chairman, J. D. Stewart; Vice-Chairman, W. L. Garlington; Secretary-Treasurer, T. S. Lynch. December 8. Attendance 30.

University of Arizona

A motion picture, entitled "Single Ridge Rubber Insulated Wire," was shown. November 6. Attendance 15.

English Contributions to Electrical Engineering; Electrical Refrigeration; History of Refrigeration, and *The Callendar Sunshine Recorder*, by Messrs. McAllister, Mitchell, Riggins and Sharpe, respectively. November 13. Attendance 14.

Automatic Combustion-Control System, by Mr. Sturges, and

Corona Loss Measurement, by Prof. J. C. Clark. November 20. Attendance 14.

Rural Electrification; Power Problems in Pulverized Fuel Plants, and *Costs of Excessive Accuracy*, by Messrs. Wilkinson, Adkinson and Antillon, respectively. December 3. Attendance 15.

University of Arkansas

Calculations of Atmospheric Pressure, by Prof. E. T. Thearle. November 9. Attendance 8.

The Oscillograph and Its Applications, by Joe Acker, student, and

Refrigeration Machinery, by E. T. Reynolds, student. November 23. Attendance 13.

Steam Railroad Electrification, by R. D. DeGood, student. Illustrated. December 7. Attendance 27.

Armour Institute of Technology

Stage Lighting and Its Control, by A. C. Flenner, student. November 4. Attendance 30.

Smoker. November 17. Attendance 60.

Engineering and Foreign Trade, by C. E. Tweedle. November 18. Attendance 60.

Terminal Development, by Mr. Morrow, Chicago and Western Indiana Railway. December 2. Attendance 150.

Brooklyn Polytechnic Institute

Engineering for Growth in the Telephone Industry, by H. L. Davis, The New York Telephone Co. October 29. Attendance 48.

Bucknell University

A talk was given by Professor Rhoades on the A. I. E. E. and Electrical Engineering at Bucknell. November 10. Attendance 65.

California Institute of Technology

Business Meeting. November 4. Attendance 22.

University of California

Radio as a Future for Electrical Engineers, by G. M. Best, Technical Editor of *Radio*. November 17. Attendance 44.

Catholic University of America

Business Meeting. The following officers were elected: President, W. S. Sparks; Vice-President, James O'Connor; Treasurer, Joseph O'Brien; Secretary, Charles Daily, Jr. October 4. Attendance 13.

The Hydroelectric Power Station of Shawinigan Falls, Canada, by Prof. MacKavanaugh. November 11. Attendance 27.

Development of Instruments for Measuring Electricity. December 10. Attendance 33.

Clarkson College of Technology

The Duodecimal System of Calculation, by H. J. Myrback. The following officers were elected: Chairman, H. J. Myrback; Secretary, W. E. Turnbull; Treasurer, R. Donald. October 5. Attendance 31.

University of Colorado

Turbine Losses and Their Determination, by Mr. Warren, General Electric Co., and

Accurate Measurement of Three-Phase Power, by H. A. Burt, Public Service Company of Colorado. November 15. Attendance 77.

Motion pictures, entitled "A Telephone Call," "A Circuit Study of a Telephone Set," and "The Electrical Transmission of Speech," were shown. November 17. Attendance 70.

Inspection trip to the Valmont Power Plant of the Public Service Company. A talk on "The Basic Principles of Turbine Testing" was given. November 18. Attendance 100.

Cooper Union

Electrification of Railways, by Ralph Ressler, student. November 19. Attendance 71.

University of Denver

Radio Direction Finding, by T. V. DeHaven, and

Electrical Practise in Lead Silver Mines of Utah, by Mr. Plank. November 5. Attendance 15.

Drexel Institute

Diesel Electric Drive, by Mr. Goldsmith. Joint meeting with A. S. M. E. November 19. Attendance 61.

University of Idaho

The A. I. E. E. and Student Branches, by H. H. Schoolfield, Vice-President, North West District, A. I. E. E. November 18. Attendance 61.

Iowa State College

The American Institute of Electrical Engineers and Its Relation to the Student, by Prof. F. A. Fish, and

The A. I. E. E. and Its Relation to Industry, by Prof. J. K. McNeely. November 9. Attendance 150.

Kansas State College

New Developments in Illumination, by Harold Batchelor, student;

Electrical Advancement in Foreign Countries, by D. Bowyer, student, and

Internal Combustion Engines as Prime Movers for Electric Railways, by Paul Ayers, student. November 15. Attendance 83.

Rural Electrification, by E. D. Bush, student. A motion picture, entitled "G. E. 60,000-K. W. Turbine Generator Set." December 6. Attendance 77.

University of Kansas

Talks on the following inspection trips: Keokuk, Iowa, Power Plant, by Elmer Bayles; Milwaukee, Wisconsin, by Delbert Stoltenberg, and Chicago, by Glenn Krieckhaus. December 2. Attendance 70.

Lehigh University

Foreign Power Development, by S. Q. Hayes, Westinghouse Electric & Mfg. Co. Illustrated. November 18. Attendance 112.

Lewis Institute

Business Meeting. November 24. Attendance 25.

Business Meeting. December 7. Attendance 15.

Marquette University

Public Utilities and Their Duty and Service to the Communities, by John Cadby, Wisconsin Utilities Association. November 11. Attendance 52.

Massachusetts Institute of Technology

Business Meeting. A motion picture, entitled "The King of the Rails," was shown. November 23. Attendance 80.

Application of Carbon Products to Industry, by P. D. Manbeck, National Carbon Co. A motion picture, entitled "Behind the Pyramids," was shown. November 29. Attendance 28.

Michigan State College

The Manufacture and Use of Turbines. October 7. Attendance 41.

The New Oil-Electric Locomotive, by Mr. B. K. Osborn. A film, entitled "Transmission Line Construction," was shown. November 3. Attendance 47.

A film on the Operation of Telephone Circuits was shown. November 23. Attendance 37.

Business Meeting. December 9. Attendance 33.

Engineering School of Milwaukee

Inspection trip to T. M. E. R. and L. Co's Public Service Building. November 11. Attendance 250.

The Application of the Glowbar, by B. A. Bovee, American Resistor Co. November 30. Attendance 25.

University of Missouri

Summer Experience with the Missouri Pacific Railroad, by J. L. Egbert, student; *Summer Experience with The Cape Girardeau Bell Telephone Co.*, by H. McLarney, student; *Summer Experience with The Southwestern Bell Telephone Co.*, by W. A. Cum; *Summer Experience with the Century Electric Co.*, by G. W. Hamilton, student, and *Summer Experience with The St. Joseph Railway, Light, Heat and Power Co.*, by V. L. Tiller. December 6. Attendance 34.

Montana State College

The Electron Theory and Electrical Engineering, by Glenn E. West. November 4. Attendance 184.

Some Problems Confronting the Young Engineer, by F. A. Lynch, and

The Progress of the Electric Power and Light Industry in the United States, by Mike Pohlod. November 18. Attendance 182.

University of Nebraska

A Graphical Conception of Engineering Work, by E. B. Roberts, Westinghouse Electric & Mfg. Co. A film, entitled "White Coal," was shown. Joint meeting with A. S. M. E. December 1. Attendance 80.

College of Engineering of the Newark Technical School

High-Quality Radio Reception, by E. Toth, student;

Radio Vacuum Tubes, by P. R. Cunliffe, student, and

Dr. Coolidge's Cathode-Ray Tube, by A. Becker, student. November 17. Attendance 25.

Design and Construction of Electrical Measuring Instruments, by J. B. Dowden, Weston Electrical Instrument Corp. December 1. Attendance 16.

University of New Hampshire

Care of Storage Batteries, by Mr. French, student, and

Tungar Rectifiers, by Mr. Beede, student. November 8. Attendance 40.

Electric Arc Welding, by Mr. Frost, student, and

Electrical Execution, by Mr. Beede, student. November 15. Attendance 38.

Hydroelectric Development in the United States, by F. W. Hussey, student, and

To Harness the Tides of Fundy, by C. A. Currier, student. November 22. Attendance 38.

University of North Carolina

A practical demonstration of high-frequency electricity was given. November 4. Attendance 35.

A Phase of Railway Electrification, by H. F. Thompson. November 18. Attendance 30.

University of North Dakota

Observations at the Western Electric Company, by Arthur Eielson, student;

Phototelegraph, by T. Hawk, student, and

Ford's Five-Day Week, by C. Shaw, student. November 1. Attendance 17.

Some Successful Experiments with Vacuum Circuit Breakers, by Elmer Johnston, student;

Trans-Atlantic Radio Transmission, by Norman Cross, student, and

Some Fundamental Principles of Radio Broadcasting, by V. D. Hauck, student. November 15. Attendance 15.

University of Notre Dame

The following motion pictures were shown: "Fifty Years of Telephone History," "Treat 'Em Right," and "Dr. Watson—Talking Movie." November 8. Attendance 1500.

The Need of Standardization of Design in Telephone Work, by F. W. Golder, Bell Telephone Co. November 23. Attendance 50.

Origin of the Algebraic Symbols, by Mr. Metrailer; *The Slide Rule*, by Mr. Galdabini; *Calculation of the Decimal Point on Slide Rule*, by Professor Hafel, and *Inductive and High-Tension Experiment*, by Messrs. Davis and Schamel. December 7. Attendance 60.

Ohio Northern University

Steam Cycles and Entropy Diagrams, by Prof. Needy. Illustrated. November 18. Attendance 27.

The Vacuum Tube and Its Application to Modern Receivers, by Mr. Kelheffer. December 2. Attendance 29.

Ohio State University

The Automatic Telephone, by Prof. W. L. Everitt, University of Michigan. Demonstrated. Dinner meeting. November 4. Attendance 120.

Ohio University

Practical Installation of Automatic Outdoor Substations, by Glenn Smith. December 8. Attendance 13.

Oklahoma Agricultural and Mechanical College

Wire Cable, by Mr. Smith. Motion pictures, entitled "How the Generator Works," and "Why of Electric Motor," were shown. December 2. Attendance 38.

Pennsylvania State College

Motion pictures, entitled "The Single Ridge" and "The Audion," were shown. November 17. Attendance 58.

University of Pittsburgh

The Personal Taste, by L. E. Papieski, student;

Manufacture of Veneer, by G. C. Bohn, student, and

Elevator Signal Devices, by V. T. Belack, student. October 22. Attendance 20.

The Radio Compass, by A. N. Curtiss, student;

Cooperative Experience with West Penn. Company, by H. R. Jones, student, and

Wheels, by G. W. Connell, student. October 29. Attendance 27.

Telephotography, by R. H. Perry, student, and

Trade Relations Between China and the U. S. A., by J. H. H. Tsui, student. November 5. Attendance 27.

A motion picture, entitled "Behind the Pyramids," was shown. November 19.

Purdue University

Commercial Radio Experiences, by K. M. White, student;

Switchboards and Protective Relay Schemes, by H. B. Stevens, student, and

The Telephoto Machine, by C. B. Jamison, student. November 16. Attendance 82.

Lightning Surges in High-Tension Transmission Lines, by Prof. Vladimir Karapetoff, Cornell University. Banquet. Joint with Indianapolis-Lafayette Section. November 30. Attendance 140.

Rensselaer Polytechnic Institute

Telephotography, by B. K. Rhoads, New York Telephone Co. Illustrated. November 9. Attendance 110.

Rhode Island State College

Modern Construction Practise, by E. G. Hendrich. November 17. Attendance 14.

Underground Cable Construction, by George Hayden. December 1. Attendance 16.

Electric Heating Appliances, by Mr. Sack. December 8. Attendance 14.

Rose Polytechnic Institute

The Uses of the Vacuum Tube, by B. A. Howlett. Illustrated. November 17. Attendance 46.

South Dakota State School of Mines

Business Meeting. December 9. Attendance 13.

University of South Dakota

Dimensional Analysis, by Mr. Muchow. November 10. Attendance 10.

Telephone Transmission, by Mr. Nelles. December 8. Attendance 8.

University of Southern California

Business Meeting. October 14. Attendance 33.

Texas Agricultural and Mechanical College

General Electric and College Students, by L. T. Blaisdell, General Electric Co. December 3. Attendance 210.

Virginia Military Institute

Our Railroads, by J. D. Taylor;

Otheographys, by P. R. Spracher;

Protecting Oil Tanks from Lightning, by R. P. Williamson, and

Distinctive Features of Hydroelectric Construction, by C. E. Kilbourne. October 16. Attendance 23.

A motion picture, entitled "The Panama Canal," was shown. November 27. Attendance 24.

Virginia Polytechnic Institute

Manufacturing by Electric Heat, by L. B. Proctor, and

Railroad Signaling, by C. W. Hines. November 18. Attendance 15.

State College of Washington

Talk by H. H. Schoolfield, Vice-President, North West District, A. I. E. E. Pictures of the Pacific Power and Light Company's project on the Clearwater River were shown. November 18. Attendance 152.

Washington University

Railway Signaling, by Dyke Meyer. November 11. Attendance 25.

A motion picture, entitled "The Single Ridge," was shown. Joint with A. S. M. E. November 24. Attendance 30.

Washington and Lee University

Fundamental Facts about Radium, by Bernard Yoepp and R. E. Kepler. December 3. Attendance 20.

University of Washington

Ross' Theory of Light, by J. D. Ross, Seattle Lighting Department. December 1. Attendance 50.

West Virginia University

Repair of Underground Cables, by K. D. Stewart; *Storage Batteries*, by I. L. Smith; *An Automatic Hydroelectric Plant*, by F. M. Farry; *Good Light—An Oil for Human Machines*, by W. T. Meyers; *Making Wiring Diagrams*, by E. H. Braid; *Porcelain as an Insulator*, by C. B. Binns; *Machine-Shop Transportation*, by R. O. Pletcher; *Landing New Atlantic Cable*, by G. B. Pyles, and *Electrically Operated Bridges*, by G. R. Latham. November 15. Attendance 37.

The Student Engineer and Accident Prevention, by W. F. Davis; *Inside-Frosted Lamps*, by S. J. Donley; *Lightning Arresters*, by W. H. Nuhfer; *Public Speaking and the Engineer*, by Albert Izzo; *A Record Construction of Pole Lines*, by S. C. Hill; *Construction of Commutating Poles*, by James Cricchi; *Detection of Sound Waves*, by C. Walsh, and *High-Speed Circuit Breakers*, by G. R. Latham. November 22. Attendance 37.

Worcester Polytechnic Institute

The Defeat of the Submarine, by Prof. H. B. Smith. Illustrated. October 26. Attendance 107.

Motion pictures, entitled "Through the Switchboard," "A Telephone Call," and "The Magic of Transmission," were shown. November 23. Attendance 110.

Past Section Meetings

Akron

Graphic Instruments in Industry, by Dr. D. J. Angus, Esterline-Angus Co. Illustrated. November 18. Attendance 35.

Baltimore

Transportation Problems, by J. H. Cornwell, Baltimore and Ohio Railroad. Joint meeting with A. S. M. E. and the Engineers' Club of Baltimore. A dinner preceded the meeting. October 14. Attendance 88.

New Electronic Rectifier, by E. W. Breisch, Westinghouse Electric & Mfg. Co. A dinner preceded the meeting. November 19. Attendance 90.

Boston

New Landmarks in Electrical Communication, by P. B. Findley, Bell Telephone Laboratories. Illustrated. November 16. Attendance 128.

The Engineer in Civic Affairs, by D. S. Kimball, Cornell University. December 9. Attendance 35.

Chicago

Why and How of the Modern Power Plant, by Francis Hodgkinson, Westinghouse Electric & Mfg. Co. Joint meeting with Electrical Section of the Western Society of Engineers. November 22. Attendance 215.

Cincinnati

Large Mercury Arc Rectifiers, by O. K. Marti, American Brown Boveri Corp. Illustrated with slides. November 11. Attendance 71.

Cleveland

Inspection trips to Avon Power Plant of the Cleveland Electric Illuminating Co. Joint with the Association of Iron and Steel Electrical Engineers. November 18. Attendance 450.

Connecticut

Hydroelectric Power as it Will Affect Connecticut Industries, by C. A. Powel, Westinghouse Electric & Mfg. Co. Illustrated with slides. November 2. Attendance 80.

Latest Developments in Carrier Currents, by G. G. Langdon, General Electric Co. Illustrated with slides. November 23. Attendance 80.

Denver

Inspection trip to the Valmont Plant of the Public Service Company of Colorado. November 18. Attendance 135.

Detroit-Ann Arbor

The Position of the Engineer, by B. G. Jamieson, Vice-President, District No. 5, A. I. E. E., and

Electrical Transmission of Power, by Dr. J. Slepian, Westinghouse Electric & Mfg. Co. A dinner preceded the meeting. November 9. Attendance 283.

Erie

The Resistor Electric Furnace and Some of Its Applications, by N. R. Stansel, General Electric Co. Illustrated with slides. November 16. Attendance 85.

Fort Wayne

Inspection trip to the new gas plant of the Northern Indiana Public Service Co. November 18. Attendance 90.

Indianapolis-Lafayette

Radio—Past, Present and Future, by C. W. Horn, Westinghouse Electric & Mfg. Co. November 19. Attendance 70.

Traveling Waves Due to Lightning, by V. Karapetoff, Cornell University. November 30. Attendance 145.

Ithaca

Tendencies of Electrical Engineering Practise, by D. C. Jackson, Massachusetts Institute of Technology. November 11. Attendance 50.

Kansas City

The Use of High Voltage for Testing Materials, by D. D. Clarke, Kansas City Power and Light Co. Motion pictures showing automotive ignition were shown. November 22. Attendance 44.

Lehigh Valley

Modern Electricity and Its Application to Transportation and Industry, by W. S. Murray, Consulting Engineer, and

Excavation by Electric Power, by W. W. Goetz, Bucyrus Shovel Co. Illustrated. November 12. Attendance 200.

Los Angeles

The Oscillograph, by Mr. Balkeslee; *Dam Sites*, by Mr. Walker, and *Responsibility of the Young Engineer*, by Mr. Hendry. This part of the program was in charge of the University of Southern California Branch.

The Vacuum Switch, by Mr. Lindvall, and *Lightning*, by Mr. Hayward. Demonstrations were made in the Norman Bridge Laboratory. This part of the program was in charge of the California Institute of Technology Branch.

A dinner preceded the meeting. December 7. Attendance 199.

Lynn

Mechanical Electrical Analogies, by Professor W. S. Franklin, Mass. Inst. of Tech. November 3. Attendance 150.

Secrets of the Amazonian Jungle, by Dr. Wm. M. McGovern. Illustrated with motion pictures and slides. November 17. Attendance 1000.

The Making and Application of Carbon Brushes, by P. F. Manbeck, National Carbon Co. Illustrated with motion pictures. November 30. Attendance 110.

Madison

Operation of Automatic Hydroelectric Apparatus, by C. W. Place, General Electric Co. A motion picture, entitled "Distributor-Type Supervisory Control," was also shown. November 22. Attendance 39.

Milwaukee

Arc Welding, by K. L. Hansen, Consulting Engineer. Illustrated with motion pictures. December 1. Attendance 54.

Minnesota

Electricity in Europe, by E. A. Stuart, University of Minnesota. Illustrated with slides. November 29. Attendance 35.

Philadelphia

Landmarks of Communication, by P. B. Findley, Bell Telephone Laboratories. November 8. Attendance 80.

Pittsburgh

Economic Conditions Affecting the Electrical Business in the World's Markets, by S. L. Nicholson, Westinghouse Electric & Mfg. Co. November 9. Attendance 214.

Pittsfield

The Raising of the S-51, by Comdr. Edward Ellsberg. November 16. Attendance 750.

Transmission of Pictures by Wire, by J. W. Horton, Bell Telephone Co. November 30. Attendance 510.

Mechanism of Dielectric Breakdown, by W. A. Del Mar, Habirshaw Electric Cable and Wire Corp. December 8. Attendance 70.

Providence

Null Methods for Checking Power-Plant Performance, by L. O. Heath, Leeds and Northrup Co. Joint meeting with Providence Engineering Society. November 16. Attendance 70.

Rochester

Electric Typewriters, by R. G. Thompson, North East Electric Co. November 5. Attendance 112.

Importance of Laboratory Measurements in Design of Radio Receivers, by W. A. McDonald, Hazeltine Corporation. Illustrated with slides. November 30. Attendance 82.

St. Louis

The Public Utility Engineer's Privileges and Responsibilities, by B. H. Peck. November 17. Attendance 21.

Sharon

Lightning Protection, by Dr. Joseph Slepian, Westinghouse Electric & Mfg. Co. A talk was also given by C. C. Chesney, National President, A. I. E. E., on his recent trip to the Pacific Coast. December 8. Attendance 150.

Springfield

Lightning Arresters, by A. L. Atherton, Westinghouse Electric & Mfg. Co. Illustrated with slides. November 15. Attendance 38.

San Francisco

Research and Standardization, by C. C. Chesney, National President, A. I. E. E.;

Lightning, by F. W. Peek, Jr., General Electric Co., and

Lightning Protection, by K. B. McEachron, General Electric Co. September 17. Attendance 200.

The Thermionic Light Tube, by A. W. Copley, Westinghouse Electric & Mfg. Co. Illustrated with demonstrations. October 22. Attendance 90.

Schenectady

The Mercury Vapor Process, by W. L. R. Emmet, General Electric Co. Illustrated with slides. December 3. Attendance 200.

Seattle

The Manufacture, Shipment and Installation of High-Tension Submarine Cables, by M. T. Crawford, Puget Sound Power and Light Co. Illustrated with films. October 27. Attendance 114.

Spokane

The Development of the 10,000-Kw. Hydroelectric Plant at Lewiston, Idaho, by H. H. Schoolfield, Pacific Power and Light Co. Joint meeting with A. S. M. E. November 19. Attendance 50.

Toledo

Single-Phase Motors, by Harry Jeannin. November 12. Attendance 24.

Radio in the Home, by E. B. Featherstone, Libbey High School. Ladies Night. December 10. Attendance 60.

Toronto

Law of Contracts, by W. G. Hanna, Hydroelectric Power Commission. November 5. Attendance 62.

Methods of Control of the Central Ontario System, by C. F. Publow, Hydroelectric Power Commission. Illustrated with slides. November 19. Attendance 75.

Urbana

Lightning and Lightning Arresters, by A. L. Atherton, Westinghouse Electric and Mfg. Co. December 8. Attendance 110.

Utah

Romance of Radio, by F. H. Talbot, General Electric Co. November 18. Attendance 55.

Washington

Present-Day Problems of Electric Street-Railway Systems, by J. H. Hanna, Capital Traction Co. November 30. Attendance 37.

Worcester

New Landmarks in Electrical Communication, by P. B. Findley, Bell Telephone Laboratories. Illustrated with slides and moving pictures. November 15. Attendance 100.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED DECEMBER 10, 1926

ABBOTT, ARTHUR CALDWELL, Shawinigan Water & Power Co., 299 Pine Ave. W., Montreal, P. Q., Can.

ABBOTT, THOMAS ALLAN, Instructor, Sheffield Scientific School, Yale University, 10 Hillhouse Ave., New Haven, Conn.

ALGER, EDGAR, Chief Electrical Draftsman, Bethlehem Shipbuilding Corp., Quincy, Mass.

*ANDREWS, JOHN LESLIE, Test Engineer, Cape Fear Steam Electric Station, Carolina Power & Light Co., Moncure, N. C.

BAIR, BALFORD, Sales Engineer, 2-133 General Motors Bldg., Detroit, Mich.

BECK, CHARLES B., Partner, Beck Bros., 3640-42 N. Second St., Philadelphia, Pa.

*BELL, NORMAN WESLEY, Asst. Engineer, Gibbs & Hill, Inc., Penna. Sta., New York; res., Brooklyn, N. Y.

*BISHOP, NATHANIEL, Apparatus Development Dept., Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

*BOWMAN, CURTIS FRANKLIN, Service Investigator, Distribution Engg. Dept., Commonwealth Edison Co., Chicago, Ill.

BRAUDE, ARTHUR NATHANIEL, Ass't. Cable Engineer, India Rubber Gutta-Percha & Telegraph Works Co., Ltd., Silvertown, London, Eng.

BROWN, GEORGE N., Manager, Atlanta Office, Okonite Co., 1510-11 Candler Bldg., Atlanta, Ga.

BRUNO, SIMONE FRANK, Electrical Expert, General Electric Co., 627 Greenwich St., New York; res., Brooklyn, N. Y.

BRYANT, LEVI A., Supervisor, Underground Dept., The Dayton Power & Light Co., 50 S. Jefferson St., Dayton, Ohio.

BURESCH, ERNEST WALTER, Contracting, 1016 Caton Ave., Brooklyn, N. Y.

CAMPBELL, FRANK WOODLIFFE, Shift Engineer, Elec. Dept., Nottingham Corp., Talbot St., Nottingham, Eng.

CARSON, LOUIS, Supervisor of Special Studies, Western Electric Co., 268 W. 36th St., New York, N. Y.

CHUNKO, P. P., Sales Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Swissvale, Pa.

*CLEAVELAND, VINCENT MATTHIAS, Montana-Dakota Power Co., Williston, N. Dak.

CLOSE, GERALD A., Electrical Engineer & Contractor, 18 Monument Sq., Portland, Me.

COLE, IRVING V., Secretary & General Manager, Lexington Electric Prod Co., 419 E. 24th St., New York, N. Y.

COLYER, ALEXANDER RICHARD, In charge, Standardizing Laboratory, New York Edison Co., 92 Vandam St., New York; res., Huntington, N. Y.

CONE, WILLIAM BENSON, Chief Electrician, Shevlin-Hixon Co., Bend, Ore.

DOOLITTLE, FRED B., Radio Engineer, Operating Dept., So. California Edison Co., Edison Bldg., Los Angeles; res., Glendale, Calif.

EIN, SAM, Power Station Operator, Illinois Steel Co., South Chicago, Ill.; res., Hammond, Ind.

ESCHMANN, WILLIAM GEORGE, Tool Designer, Splitdorf Electrical Co., 392 High St., Newark; res., Morristown, N. J.

GATES, STUART HOPE, Fieldman, Southern Bell Tel. & Tel. Co., 1111 Republic Bldg., Louisville, Ky.

GEORGIEV, ALEXANDER M., Asst., Experimental Dept., Eisemann Magneto Corp., 32-33rd St., Brooklyn, N. Y.

GILLMOR, JAMES, Load Supervising Engineer, Toronto Hydro-Electric System, Cor. Duncan & Nelson Sts., Toronto, Ont., Can.

GLASGOW, ERNEST M., Supt., Russell & Stoll Co., 53 Rose St., New York, N. Y.

GREENE, RONALD EARLE, Construction Bureau, Detroit Edison Co., 2000 Second St., Detroit, Mich.

HABERER, JULIEN P. A., Turbine Engg. Dept., General Electric Co., Lynn, Mass.

HAMMOND, CHARLES SYDNEY, Asst. to General Sales Mgr., Georgia Railway & Power Co., 301 Electric & Gas Bldg., Atlanta, Ga.

*HAMMOND, RICHARD AUSTIN, Construction Foreman, Engg. Dept., General Electric Co., 510 Dwight Bldg., Kansas City, Mo.

HEIM, HOWARD J., Instructor, Elec. Engg. Dept., Purdue University, Lafayette, Ind.

HENDRICKSON, HENRICH ARVID, Asst. Standards Engineer, Engg. Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.

HILDEBRAND, THOMAS F., Distribution Engineer, Indiana General Service Co., Marion, Ind.

HODGMAN, JAMES WILDING, General Electric Co., 1635 Broadway, Fort Wayne, Ind.

*HOLMES, MAURICE COFFYN, Turbine Engg. Dept., General Electric Co., West Lynn; res., Lynn, Mass.

HORNBERGER, RUSSELL G., Asst. Engineer, Elec. Dept., U. S. Bureau of Reclamation, 1441 Welton St., Denver, Colo.

*HULL, RANDOLPH MATTHEWS, Engineer, Distribution Dept., Alabama Power Co., Birmingham, Ala.

JORGENSON, LOUIS MARK, Asst. Professor, Elec. Engg. Dept., Kansas State Agricultural College, Manhattan, Kans.

KAMINSKY, MORRIS M., Designing Engr., W. J. Holliday & Co., 522 W. McCarty St., Cons. Engr., 816 Continental Bank Bldg., Indianapolis, Ind.

KASINDORF, SIDNEY, Vice-President & Treasurer, Commodore Radio Corp., 144 E. 42nd St., New York, N. Y.

KOENIG, EMIL L., Engineer, Tax Consultant, 26 Cortlandt St., New York, N. Y. and Washington, D. C.

KOMIVES, LADISLAS I., Electrical Engineer, The Detroit Edison Co., 2000 Second Blvd., Detroit, Mich.

KORMENDY, LOUIS, Draftsman, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

*KOVACH, ALEXANDER JOSEPH, Machinist, Richard Bros., Detroit, Mich.

*KRONEBERG, ALEX ALEXEVICH, Apprentice Engineer, Employment Dept., So. California Edison Co., Los Angeles, Calif.

LEWALD, HAROLD P., Director of Service Dept. & Repair Shop, K. & B. Elec. Equipment Co., Inc., 127 E. 23rd St., New York, N. Y.

MALMSTROM, A. L., Electrical Engineer, Detroit Edison Co., 2000 Second St., Detroit, Mich.

MANASERI, BENJAMIN B., Assistant, Division Electrician's Office, Postal Telegraph Cable Co., 20 Broa dSt., New York, N. Y.

MANUEL, ELMER J., Foreman, Cable Testing & Fault Location, Detroit Edison Co., 2000 Second St., Detroit, Mich.

*McCREA, WILLIAM S., JR., Draftsman, Washington Water Power Co., Spokane, Wash.

McHENRY, WILLIAM C., Pennsylvania Power & Light Co., 802 Hamilton St., Allentown, Pa.
MILLER, JAMES E., Switchboard Operator, Kentucky Utilities Co., Four Mile, Ky.
MOORE, EDWARD ROYAL, Elec. Engr., Detroit Edison Co., 2000 Second Ave., Detroit; res., Highland Park, Mich.
MORRISON, L. HARTWELL, Chief Electrician & Mechanic, Cia. Mexicana de Terrenos Y Petroleo, S. A., Frontera, Tabasco; for mail, Salto de Agua, Chiapas, Mex.
NELSON, WILLIAM L., Electrical Engineer, The Ohio Public Service Co., Elyria, Ohio.
NIEMOELLER, ELMER, Engineer, General Engg. Dept., The Pacific Tel. & Tel. Co., 740 S. Olive St., Los Angeles, Calif.
OLVING, BROR GUSTAF, Draftsman, New York Edison Co., 140th St. & Rider Ave., New York, N. Y.
ORBELL, REGINALD JOHN, Engineering Assistant, Thames Valley Power Board, Te Aroha; for mail, Timaru, N. Z.
PERUZZI, ENRICO, Electrical Engineer, Detroit Edison Co., 2000 Second St., Detroit, Mich.
PETERSON, ALFRED WILLIAM, Supt. of Traffic, Porto Rico Telephone Co., San Juan, Porto Rico.
POGGEMEYER, BURNETT H., Chief Electrician, U. S. Gypsum Co., Genoa, Ohio.
POYITT, DAVID GOULD, Asst. Engineer, Electricity Dept., Municipal Council of Sydney, Sydney, N. S. W., Aust.
PRINGLE, JOHN BUCHARAN, Asst. Cable Engineer, Northern Electric Co., 121 Shearer St., Montreal, P. Q., Can.
RASMUSSEN, FREDERICK JESSEN, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Montclair, N. J.
RODGARD, HAROLD, Draftsman, The New York Edison Co., 708 First Ave., New York; res., Brooklyn, N. Y.
ROONEY, FORREST H., Chief Electrician, Columbia Steel Corp., Provo, Utah.
ROWLAND, WALTER BRABROOK, Manager for Cuba, Union Carbide & Carbon Corporations, Habana, Cuba.
SARGENT, JOHN ALEXANDER, Second Substation Operator, Public Works Dept., Khandallah, N. Z.
SCHENCK, FRED W., Colliery Electrician, Pine Hill Coal Co., 613 N. 2nd St., Minersville, Pa.
SHEARS, CURTIS CHARLES, Sales Engineer, Otis Elevator Co., 300 E. 8th St., Los Angeles, Calif.
SCHOBERTH, GUSTAV, Electrician, New York Edison Co., New York, N. Y.
SIEWERT, DANIEL ROBERT, Construction Foreman, General Electric Co., 510 Dwight Bldg., Kansas City, Mo.
SINCLAIR, DAVID, 218 Garfield Place, Brooklyn, N. Y.
SKEELS, WILLIAM ROY, Electrician, Postal-Telegraph Cable Co., Postal Telegraph Bldg. Chicago, Ill.
SLEPIAN, ARTHUR, Asst. General Manager, Wheeler Insulated Wire Co., Bridgeport, Conn.
TURPIN, C. E., Chief Electrician, American Smelting & Refining Co., 6th & Douglas Sts., Omaha, Nebr.
WARFIELD, CALVIN NORWOOD, Associate Professor, University of Richmond, Richmond, Va.
WORK, HANS ROLAND, Electrical Engineer, Crocker-Wheeler Electric Mfg. Co., Ampere, N. J.; res., New York, N. Y.
ZIELINSKI, FRANCIS JOSEPH, Student Engineer, General Electric Co., 5 Benefit Terrace, Worcester, Mass.
Total 82.
*Formerly enrolled students.

ASSOCIATES RE-ELECTED DECEMBER 10, 1926

BARNEY, HOWARD S., Supt., Chester County Light & Power Co., 125 East State St., Kennett Square, Pa.
COX, PAUL E., Engineer, Georgia Railway & Power Co., Atlanta, Ga.
PERLEWITZ, JAMES MARK, Sales Manager, Graybar Electric Co., 167 W. 2nd South St., Salt Lake City, Utah.

ASSOCIATE RE-INSTATED DECEMBER 10, 1926

LORCH, ALBERT, President, Welding Service Corp.; Manager, Industrial Power Electric Co., Lakewood Ave., Baltimore, Md.

MEMBERS ELECTED DECEMBER 10, 1926

CONNOR, FRANCIS A., Sales Engineer, General Electric Co., 1309 Oliver Bldg., Pittsburgh, Pa.
HAWKES, CHRISTIAN JOHN, Engineer, Seattle Branch, The Electric Storage Battery Co., 1041 Railroad Ave. South, Seattle, Wash.
McLAUCHLAN, CHARLES DAVID, State Sectional Engineer, Postal Dept., Telegraph & County Telephones, Perth, Western Aust.
MILLER, WILLIAM COOK, Supt., Electrical System, The Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
PRIOR, FRANK OSCAR, Supt., Electric Plants, Midwest Refining Co., Casper, Wyo.
READING, ARTHUR LAURENCE, Supt. of Substation, West Kootenay Power & Light Co., Trail, B. C.
TAYLOR, HARVEY BIRCHARD, Vice-President, The William Cramp & Sons Ship & Engine Building Co., Richmond & Norris Sts., Philadelphia, Pa.
TEFFT, WILLIAM WOLCOTT, Vice-President & Chief Engineer, Commonwealth Power Corp., 224 Michigan Ave., Jackson, Mich.
THORNWELL, EDWARD ALLISON, Manufacturer's Agent, 1510-11 Candler Bldg., Atlanta, Ga.
VAUGHAN, FORT FARINHOLT, Electrical Engineer, Phoenix Utility Co., 237 S. W. 4th St., Miami, Fla.
WELBOURN, BURKEWOOD, Chief Construction Engineer, British Insulated Cables, Ltd., Prescot, Lancanshire; res., Rainhill, Eng.
WERTH, JAMES ROBERT, General Supt., Light, Power & Gas, Appalachian Electric Power Co., Lynchburg, Va.
WIDELL, BERNDT A., Jr., Engineer, Railway Motor Costs, General Electric Co., East Lake Road, Erie, Pa.

TRANSFERED TO GRADE OF FELLOW DECEMBER 10, 1926

BEAVER, J. LYNFORD, Associate Professor of Electrical Engineering, Lehigh University, Bethlehem, Pa.
LEE, LOUIS R., Engineer, Commonwealth Power Corporation, Jackson, Michigan.
MOURADIAN, H., Toll Fundamental Plan Engineer, Bell Tel. Co. of Pennsylvania, Philadelphia, Pa.
PANTER, THOMAS ALFRED, Electrical Engineer, Bureau of Power & Light, City of Los Angeles, Los Angeles, Calif.
ROSSMAN, ALLEN M., Electrical Engineer, Sargent & Lundy, Chicago, Ill.
SINDEBAND, M. L., Vice President, American Gas & Electric Company, New York, N. Y.

TRANSFERRED TO GRADE OF MEMBER DECEMBER 10, 1026

ADAMS, LEE F., Commercial Engineer, General Electric Company, Schenectady, N. Y.
ARMOR, JAMES C., Electrical Engineer, Pittsburgh Transformer Company, Pittsburgh, Pa.
BACHRACH, ALFRED, Commercial Engineer, General Electrical Company, Los Angeles, Calif.
BENNETT, CLARENCE S., Construction Engineer, General Electric Company, Portland, Oregon.
BERKLEY, H. WALTER, Electrical Engineer, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.
BILLHIMER, FRANK M., General Engineer, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.
BOISSONNAULT, F. L., Control Engineer, Westinghouse Electric & Mfg. Company, San Francisco, Calif.
BROWN, STEWART K., Assistant Superintendent, Meter Department, Potomac Electric Power Company, Washington, D. C.
CAROTHERS, ROBERT M., In Administrative Charge, Flow Meter Regular Engineering Department, General Electric Company, Schenectady, N. Y.
CROSBY, GEORGE L., Vice President (Sales), Roller-Smith Company, New York, N. Y.
CURRIER, PHILLIP M., Electrical Engineer, General Electric Company, Schenectady, N. Y.
DART, HARRY F., Radio Engineer, Westinghouse Lamp Company, Bloomfield, N. J.
DICKINSON, WILBUR K., Electrical Engineer, General Electric Company, West Lynn, Mass.
DUNCAN, P. M., Electrical Engineer, Allis-Chalmers Mfg. Company, Milwaukee, Wis.
DUNN, STEPHEN E., Sales Engineer, Clapp and LaMorse, San Francisco, Calif.
EDWARDS, GEORGE DeFOREST, Telephone Engineer, Bell Telephone Laboratories, Inc., New York, N. Y.
ELDER, L. R., Manager, Motor Department, General Electric Company, Portland, Oregon.
FALLOON, E. J., Hydraulic Engineer, Glen Alden Coal Company, Scranton, Pa.
FETHERLING, H. G., Sales Engineer, General Electric Company, Pittsburgh, Pa.
FLANNERY, DANIEL THOMAS, Assistant Engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ont., Canada.
FRIIS, HAROLD T., Research Engineer, Bell Telephone Laboratories, Inc., Cliffwood, N. J.
GARMAN, CHARLES P., Electrical Engineer, Dept. of Water and Power, Los Angeles, Calif.
GASSAWAY, STEPHEN G., Assistant Manager, Commercial Dept., Oklahoma Gas & Electric Company, Oklahoma City, Okla.
GEORGE, CLIFFORD H., Superintendent, Light and Power, Puget Sound Power & Light Company, Wenatchee, Wash.
GRAY, ROBERT L., Electrical Engineer Tararua Electric Power Board, Eketahuna New Zealand.
HAGAR, GEORGE H., Assistant to General Superintendent, Great Western Power Company, San Francisco, Calif.
HAMILTON, WILLIAM STORRS H., Electrical Engineer, Railway Engineering Department, General Electric Company, Schenectady, N. Y.
HANSEN, EDMUND H., Research Engineer, Radio Corporation of America, New York, N. Y.
HOGG, CHARLES J., Engineer, New England Tel. & Tel. Company, Boston, Mass.
KOBROCK, JOHN P., Division Plant Engineer, New England Tel. & Tel. Company, Boston, Mass.
KRIEGSMANN, ARNOLD E., Assistant Engineer, Hodenpyl, Hardy & Company, Inc., New York, N. Y.
LAMPE, J. HAROLD, Instructor in Electrical Engineering, Johns Hopkins University, Baltimore, Md.
LAWRENCE, ROGER C., Electrical Engineer, American Steel & Wire Company, Cleveland, Ohio.
LEWIS, HOWARD O., Assistant Engineer, Electrical Engineering Department, Boston Elevated Railway, Boston, Mass.
LOVELL, CLEMENS M., Designing Engineer, Moloney Electric Company, St. Louis, Mo.

LYON, WILLIAM R., Electrical Engineer, Products Protection Corporation, New Haven, Conn.
MARTIN, HARRISON A., Assistant Electrical Engineer, Electric Bond & Share Company, New York, N. Y.
MAXSTADT, FRANCIS W., Instructor of Electrical Engineering, California Institute of Technology, Pasadena, Calif.
McLAGAN, ERNEST G., Sales Engineer, Allis-Chalmers Mfg. Company, St. Louis, Mo.
MEREDITH, GAILEN E., Superintendent, Engineering Research Laboratory, Kansas City Power and Light Company, Kansas City, Mo.
MILLER, WILLIAM J., Dean of Engineering, Texas Technological College, Lubbock, Texas.
NEEDHAM, OLLIE, Electrical Engineer, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.
NELSON, ARTHUR L., Manager, Construction Dept., Jackson & Moreland, Boston, Mass.
PANCOAST, D. F., Consulting Engineer, Cleveland, Ohio.
ROBBINS, FRANCIS J., Supt. of Distribution, Grays Harbor Railway and Light Company, Aberdeen, Wash.
SAMUELS, IRVING, President, Automatic Devices Company, President, Samuels Stabilarc Company, Allentown, Pa.
SHEPARD, WILLIAM M., Vice President and General Agent, The California Oregon Power Company, Medford, Oregon.
SMITH, CHARLES GROVER, Physicist, Raytheon Mfg. Company, Cambridge, Mass.
SMITH, WALTER C., Sales Engineer, Meters and Transformers, General Electric Company, San Francisco, Calif.
STAUFFACHER, EDWIN R., Superintendent of Protection, Southern California Edison Company, Los Angeles, Calif.
THOMPSON, RUSSELL G., Assistant Superintendent, North East Electric Company, Rochester, N. Y.
TRAWICK, HENRY PHILLIPS, Proposal Engineer, Switchboard Sales, General Electric Company, Baltimore, Md.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held December 7, 1926, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

SUTHERLAND, GEORGE, Electrical Engineer, Duquesne Light Co., Pittsburgh, Pa.

To Grade of Member

BALLARD, HAROLD L., Supervisor of Instruction, Michigan Bell Tel. Co., Detroit, Mich.
BESSESEN, B. B., Instructor in Electrical Engineering, Oregon Agricultural College, Corvallis, Ore.
COOVER, WILLIAM E., Electrical Engineering Dept., Brooklyn Edison Co., Brooklyn, N. Y.
CRAFT, FRANCIS M., Chief Engineer, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
CREECY, C. E., Telephone Engineer, Chesapeake & Potomac Tel. Co., Washington, D. C.
CRUICKSHANK, CHARLES B., Asst. Cable Engineer, Interborough Rapid Transit Co., New York, N. Y.
GRAFF, JOHN T., Plant Results Supervisor, Chesapeake & Potomac Tel. Co., Washington, D. C.
HEBERT, JOSEPH A., Division Plant Engineer, Southern Bell Tel. Co., Charlotte, N. C.
HIGGINS, N. B., Asst. Chief Engineer, Penn. Water & Power Co., Baltimore, Md.
KARUVEN, MULIYIL, Dy. Supt., Mills Division, Andhra Valley Power Supply Co., Ltd. & Tata Hydro Elec. P. S. Co., Bombay, India.
KNISKERN, FLOYD B., Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
LAFORE, J. A., Secretary and General Manager, John Lang Paper Co., Philadelphia, Pa.
LOYE, DONALD P., Telephone Engineer, American Tel. & Tel. Co., New York, N. Y.
McCLURE, MILTON B., Engineer, Georgia Railway & Power Co., Atlanta, Ga.
PORTER, HARRY L., District Manager, Verne W. Shear & Co., Cleveland, Ohio.
SHEPARD, WILLIAM M., Vice-President and General Agent, California Oregon Power Co., Medford, Ore.
SHIRLEY, ERNEST R., Asst. Switchboard Engineer, Canadian General Electric Co., Ltd., Peterboro, Ont.
TRABERT, ARCHIE W., Electrical Engineer, Industrial Electric Service Co., Aberdeen, Wash.
VAILE, HORACE S., Industrial Marketing Counselor, McGraw Hill Publishing Co., New York, N. Y.
VARIAN, CLARENCE E., Electrical Engineer, Spicer Mfg. Corp., South Plainfield, N. J.
WACKER, HERMAN, Telephone Engineer, Chesapeake & Potomac Tel. Co., Washington, D. C.
WISE, LYLE D., San Francisco, Calif.
ZIEGLER, EDWARD F., Designing Engineer, Duquesne Light Co., Pittsburgh, Pa.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1927.

Agnew, E. J., Western Union Telegraph Co., New York, N. Y.
Albert, A. L., Oregon Agricultural College, Corvallis, Ore.
Ahlberg, A. E., General Appraisal Co., Seattle, Wash.
Ahlquist, R. W., University of Pittsburgh, Pittsburgh, Pa.
Albrecht, E. G., Tri-State Tel. & Tel. Co., St. Paul, Minn.
Allen, W. M., Washington Water Power Co., Spokane, Wash.
Ambrose, J. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Amrhein, G. H., New York Telephone Co., New York, N. Y.
Andres, J. F., So. California Telephone Co., Los Angeles, Calif.
Anfang, E. L., Allis-Chalmers Mfg. Co., West Allis, Wis.
Arrouet, M., Ingenieur Ste. Metallurgie de Montricher, Paris, France. (For mail, New York, N. Y.)
Ashley, J. M., Youngstown Sheet & Tube Co., Youngstown, Ohio
Augustine, E. T., Philadelphia Electric Co., Philadelphia, Pa.
Ayres, C. C., Jr., General Electric Co., Schenectady, N. Y.
Bailly, O. R., School of Engineering of Milwaukee, Milwaukee, Wis.
Baker, B. P., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Baker, C. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Balaguer, M. M., International Tel. & Tel. Corp., New York, N. Y.
Balfour, M. W., Public Service Co. of No. Ill., Chicago, Ill.
Barbee, W. L., Puget Sound Power & Light Co., Seattle, Wash.
Barry, J. M., Bureau of Standards, Washington, D. C.
Bartholomaeus, J., Chesapeake & Potomac Telephone Co., Baltimore, Md.
Bartling, H. A., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Barton, L. C., Westinghouse Elec. & Mfg. Co., Cincinnati, Ohio (Applicant for re-election.)
Batchelor, A. J., Toledo Edison Co., Toledo, Ohio
Bauer, C., Public Service Electric & Gas Co., Newark, N. J.
Beardsley, B., Western Union Telegraph Co., New York, N. Y.
Beattie, C. S., Public Service Production Co., Newark, N. J.
Becker, H. A., International Harvester Co., Chicago, Ill.
Belcher, A. J., General Electric Co., Schenectady, N. Y.
Benedict, R. R., University of Wisconsin, Madison, Wis.
Benett, C. M., Rome Wire Co., Rome, N. Y.
Bennion, H. S., (Member), Director of Engg., N. E. L. A., New York, N. Y.
Blackstone, W. S., Youngstown Sheet & Tube Co., Youngstown, Ohio
Blanchet, O. J., Morse Twist Drill & Machine Co., New Bedford, Mass.
Blanton, W. B., Western Union Telegraph Co., New York, N. Y.
Bosch, L. L., Columbia Engineering & Management Corp., Cincinnati, Ohio
Bowser, C., (Fellow), Virginia Railway Co., Narrows, Va.
Boyd, O. H., Canadian General Electric Co., Peterboro, Ont. Can.
Boyle, W. E., Rome Wire Co., Rome, N. Y.
Brady, R. E., (Member), Warren Street Railway Co., Warren, Pa.
Brantley, E. C., City of Danville Electric Dept., Danville, Va. (Applicant for re-election.)
Brantley, E. P., (Member), Georgia Railway & Power Co., Atlanta, Ga.
Briden, O. W., Brown University, Providence, R. I.
Brizius, H. W., Western Electric Co., New York, N. Y.
Broadwell, E., General Electric Co., Schenectady, N. Y.
Brolly, A. H., Harvard University, Cambridge, Mass.
Buettger, W. A., Philadelphia Rural Transit, Philadelphia, Pa.
Burkholder, T. M., Edison Elec. Illuminating Co. of Boston, Boston, Mass.
Caldwell, S. H., Mass. Institute of Technology, Cambridge, Mass.
Callen, R. J., Jr., Brunswick-Balke Collender Co., New York, N. Y.
Campbell, F. W., (Member), Westinghouse Elec. & Mfg. Co., Cleveland, Ohio
Campeau, A. C., Cobbs & Mitchell Co., Valsetz, Ore.
Cassidy, J. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Catlin, A. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Chitty, W. C., (Member), Tidewater Oil Co., Bayonne, N. J.
Christiansen, P. L., (Fellow), West Indian Co., Ltd., St. Thomas, Virgin Islands of U. S. A.
Cicatelle, F. A., Brooklyn Edison Co., Brooklyn, N. Y.
Clark, B. N., with J. N. Heeney, Scarsdale, N. Y.
Commander, S. C., Mississippi A. & M. College, A. & M. College, Miss.
Cronk, J. A., Electric Storage Battery Co., Atlanta, Ga.
Cucchiarelli, A., New York Edison Co., New York, N. Y.
Dake, C. B., New York Edison Co., New York, N. Y.
Dallye, F. R., Public Service Production Co., Newark, N. J.
Datt, M., International Harvester Co., Fort Wayne, Ind.
Dausman, O. D., Michigan State College, East Lansing, Mich.
Davis, W. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Day, A. R., Great Western Power Co., San Francisco, Calif.
Dees, A. F., International Motor Co., Allentown, Pa.
Dempster, J. R., Turlock Irrigation District, Turlock, Calif.
Depperman, F. L., Western Union Tel. Co., New York, N. Y.
Diehl, C. W., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Dively, W. L., Century Electric Co., Philadelphia, Pa.
Dolan, G. A., Public Service Production Co., Newark, N. J.
Doyle, P. W., Lalance Groosjean Mfg. Co., Woodhaven, N. Y.
Duane, G. B., Otis Elevator Co., Yonkers, N. Y.
Duffus, H. B., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Eastman, F. S., General Electric Co., Seattle, Wash.
Eberhart, E. K., Bell Telephone Laboratories, Inc., New York N. Y.
Edgerton, H. E., Mass. Institute of Technology, Boston, Mass.
Edwards, R. G., Southern California Edison Co., Los Angeles, Calif.
Ekvall, H. N., Philadelphia Electric Co., Philadelphia, Pa.
Elker, H. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Enloe, R. T., So. California Edison Co., Big Creek, Calif.
Epstein, S. B., Pacific Gas & Electric Co., San Francisco, Calif.
Epting, H. D., Wagner Electric Corp., Philadelphia, Pa.
Erickson, E. H., Public Service Production Co., Newark, N. J.
Erskine, H. E., Wentworth Institute, Boston, Mass.
Evans, H. P., University of Wisconsin, Madison, Wis.
Fain, J., Philadelphia Electric Co., Philadelphia, Pa.
Farley, E. R., M. A. Farley Mercantile Co., Birmingham, Ala.
Ferguson, J. G., Bell Telephone Laboratories, Inc., New York, N. Y.
Ferguson, W. H., Atmospheric Nitrogen Corp., Syracuse, N. Y.
Fielder, T. H., Georgia Railway & Power Co., Atlanta, Ga.
Findley, P. B., Bell Telephone Laboratories, Inc., New York, N. Y.
Finley, J. H., Jr., Arkansas Power & Light Co., Little Rock, Ark.
Frenck, C. J., College of Engg., Northwestern University, Evanston, Ill.
Frentzal, A., Union Gas & Electric Co., Cincinnati, Ohio
Frey, W. L., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Gamm, O. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Gauthier, V. E., Chicago Rapid Transit Co., Chicago, Ill.
Gayle, J. DeJ., General Electric Co., Schenectady, N. Y.
Geyer, H. W., Mass. Institute of Technology, Cambridge, Mass.
Gibson, H. L., Wisconsin Power & Light Co., Beloit, Wis.
Gilman, W. McK., Jackson & Moreland, Boston, Mass.
Gimmy, N. H., Western Union Telegraph Co., Cleveland, Ohio
Gompf, A. P., Chesapeake & Potomac Telephone Co., Washington, D. C.
Goodale, E. C., Puget Sound Power & Light Co., Tacoma, Wash.
Gooding, R. F., (Member), Condit Electric Mfg. Co., Pittsburgh, Pa.
Gordon, W. S., Jr., Chicago, Milwaukee & St. Paul Rwy., Seattle, Wash.
Gould, K. E., Mass. Institute of Technology, Cambridge, Mass.
Grabar, J., M. B. Sleeper, Inc., Poughkeepsie, N. Y.
Graf, A. W., U. S. Patent Office, Washington, D. C.
Gray, D. C., General Electric Co., St. Louis, Mo.
Greavy, W. G., Western Union Tel. Co., Atlanta, Ga.
Greene, J. E., Jr., Bell Telephone Laboratories, Inc., New York, N. Y.
Greene, J. F., Victor Talking Machine Co., Buenos Aires, S. A.; for mail, Camden, N. J.
Greene, I. W., Georgia Railway & Power Co., Atlanta, Ga.
Greene, L. C., Forest Electric Co., Newark, N. J.
Grow, L. M., General Electric Co., Schenectady, N. Y.
Gruenburg, G. S., U. S. S. Saratoga, c/o Postmaster, New York, N. Y.
Gunn, D., Duquesne Light Co., Pittsburgh, Pa.
Guyer, R., Georgia Railway & Power Co., Atlanta, Ga.
Hall, E. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Hamburger, F., California Institute of Technology, Pasadena, Calif.
Hammond, B. R., Florida Power & Light Co., Lakeland. Fla.
Hankins, M. J., Bureau of Pr. & Lt., City of Los Angeles, Los Angeles, Calif.
Harris, P. R., Calumet City Public Service Co., Calumet City, Ill.
Helgason, A., Thordarson Electric Mfg. Co., Chicago, Ill.
Helwig, F. C., Toledo Edison Co., Toledo, Ohio
Henderson, M. L., General Electric Co., West Lynn, Mass.
Hendricks, C. E., General Electric Co., Schenectady, N. Y.
Hesser, H. M., L. & N. R. R. Co., Louisville, Ky.
Hildebrand, E. H., Pacific Tel. & Tel. Co., San Francisco, Calif.
Hill, R. M., General Electric Co., Schenectady, N. Y.
Hinkel, J. W., Metropolitan Edison Co., Reading, Pa.
Hiscox, W. L., Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Hoefle, A., Toledo Edison Co., Toledo, Ohio
Hooper, W. E., Alabama Power Co., Birmingham, Ala.
Hubbard, B. R., Submarine Signal Corps, Boston, Mass.
Huber, H. J. H., General Electric Co., Philadelphia, Pa.
Hull, L. M., (Member), Radio Frequency Laboratories, Boonton, N. J.
Jacobitti, E., Bell Telephone Laboratories, Inc., New York, N. Y.
Jascoviak, R. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Johnson, A. E., Pacific Gas & Electric Co., San Francisco, Calif.
Jones, C. R., Tallahasse Power Co., Badin, N. C.
Jones, M. T., So. California Edison Co., Los Angeles, Calif.
Kadan, G. F., American Tel. & Tel. Co., Selma, N. C.
Kalischer, M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Katranis, G. J., General Electric Co., Lynn, Mass.
Kemp, E. M., Great Western Power Co., Sacramento, Calif.
Kernahan, R., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Kettenhofen, L. J., Western Electric Co., New York, N. Y.
Kline, C. W., (Member), Harding Cream Co., Omaha, Nebr.
Knecht, W. G., Commonwealth Edison Co., Chicago, Ill.
La Porte, G. H., Automatic Electric Inc., New York, N. Y.
Latteman, W., General Electric Co., Schenectady, N. Y.
Law, J. C., Bessemer & Lake Erie Railroad, Greeneville, Pa.
Legler, C. H., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Lere, J. E., School of Engineering of Milwaukee, Milwaukee, Wis.
Letts, T. H., Montreal Light, Heat & Power Cons., Montreal, P. Q., Can.
Levy, R. D., International Harvester Co., Chicago, Ill.
Lince, A. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Lindquist, K. E., General Electric Co., West Lynn, Mass.
Lippert, L. H., Northern States Power Co., Sioux Falls, So. Dak.
Lo, H. C., Worcester Polytechnic Institute, Worcester, Mass.
Losie, W. E., The Detroit Edison Co., Detroit, Mich.
Ludlum, R. V., Edison Lamp Works, G. E. Co., Harrison, N. J.
Lunas, L. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Lusignan, J. T., Stanford University, Stanford University, Calif.
MacDonald, W. A., Hazeltine Corp., Hoboken, N. J.
Malinowski, F., Westchester County Park Commission, White Plains, N. Y.
Mancill, F. W., Jr., H. E. Sechrist & Co., Philadelphia, Pa.
Maner, R. C., Georgia Railway & Power Co., Atlanta, Ga.
Mason, H., (Member), Western Union Tel. Co., New York, N. Y.
Master, W., Brooklyn Edison Co., Brooklyn, N. Y.
McCarthy, A. J., Otis Elevator Co., Yonkers, N. Y.
McCoy, J. C., Pacific Gas & Electric Co., San Francisco, Calif.
McIvor, J. G., Bell Telephone Laboratories, Inc., New York, N. Y.
McKibben, W. E., General Electric Co., Schenectady, N. Y.
McKinley, R., Union Switch & Signal Co., Swissvale, Pa.
McLean, L. A., Ohio Power Co., Canton, Ohio
McMillan, J., Canadian Westinghouse Co., Hamilton, Ont., Can.
Meihoff, A. D., Northwestern Electric Co., Portland, Ore.
Mendezoff, L. M., Cleveland Electric Illuminating Co., Cleveland, Ohio
Miille, R. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Miller, J. Z., (Member), Mutual Telephone Co., Erie, Pa.
Mollman, L. A., Union Electric Light & Power Co., St. Louis, Mo.
Moaghann, W. J., New York Edison Co., New York, N. Y.
Moody, L. E., with Isaac Hathaway Francis, Philadelphia, Pa.
Moran, J. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Morley, F. W., B. F. Sturtevant Co., Hyde Park, Mass.
Morton, R. M., Canadian General Electric Co., Peterboro, Ont., Can.
Mott, E. V., Western Union Telegraph Co., New York, N. Y.
Nelson, C. H., Public Service Co. of No. Illinois, Chicago, Ill.
Nesmith, J., 2nd, Public Service Electric & Gas Co., Kearny, N. J.
Noll, E. J., General Electric Co., Philadelphia, Pa.
Nutting, D. C., Sumner, Wash.
Ock, W. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Oehler, J. F., Bethlehem Steel Co., Lackawanna, N. Y.
Olmstead, C. L., Western Union Telegraph Co., New York, N. Y.
Osgerby, F. L., The Detroit Edison Co., Detroit, Mich.
O'Sullivan, L., Montreal Light, Heat & Power Cons., Montreal, Que., Can.

Owens, E. L., Western Union Telegraph Co., New York, N. Y.
Papst, H. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Patten, E. K., The Chesapeake & Potomac Tel. Co., Baltimore, Md.
Patton, J. H., Sangamo Electric Co., Springfield, Ill.
Pauli, H. F., Thomas A. Edison Laboratories, West Orange, N. J.
Peck, G. V., Condenser Corp. of America, New York, N. Y.
Peck, W. G., School of Engineering of Milwaukee, Milwaukee, Wis.
Pennoyer, D. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Pepin, H. E., Public Service Power & Light Co., Seattle, Wash.
Petruska, J. J., Philadelphia Electric Co., Philadelphia, Pa.
Piepho, E. E., Detroit Edison Co., Detroit, Mich.
Piper, R. W., Pittsburgh Transformer Co., Atlanta, Ga.
Prudham, W. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Quinn, R. P., United Gas Improvement Co., Sioux City, Ia.
Raginsky, M. M., Research Engineer, 500 W. 190th St., New York, N. Y.
Randhawa, S. S., General Electric Co., Lynn, Mass.
Raskhodoff, N. M., American Bosch Magneto Corp., Springfield, Mass.
Roess, H., (Member), Westinghouse Elec. & Mfg. Co., Hastings, Nebr.
Rich, T. A., General Electric Co., West Lynn, Mass.
Riggs, G., Bell Telephone Laboratories, Inc., New York, N. Y.
Ritter, E. W., General Electric Co., Nela Park, Cleveland, Ohio
Robb, W. F., Bell Telephone Laboratories, Inc., New York, N. Y.
Robbins, C. L., Electrical Testing Laboratories, New York, N. Y.
Robertson, C. M., Georgia Railway & Power Co., Atlanta, Ga.
Robertson, L. M., Public Service Co. of Colorado, Denver, Colo.
Robertson, W. D., Canadian General Electric Co., Vancouver, B. C., Can.
Robinson, A. M., Bell Telephone Laboratories, Inc., New York, N. Y.
Robinson, C. P., Ideal Electric & Mfg. Co., Mansfield, Ohio
Rodiles, M. G., Co. Cubana Electricidad, Guantanamo, Cuba
Rodwin, G., Radio Corp. of America, New York, N. Y.
Rozier, H. F., with F. R. Weller, Washington, D. C.
Ruaisch, C., General Electric Co., Bronx, New York, N. Y.
Scheck, A. H., Duquesne Light Co., Pittsburgh, Pa.
Scherb, E., General Electric Co., West Philadelphia, Pa.
Schofield, J. E., Southern Colorado Power Co., Victor, Colo.
Schramm, F. B., General Electric Co., Schenectady, N. Y.
Scofield, R. W., N. Y. & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
Seecamp, J. F., Puget Sound Power & Light Co., Seattle, Wash.
Seymour, R. W., Electric Storage Battery Co., Atlanta, Ga.
Shaw, R. M., Signal Corps, U. S. A., Camp Lewis, Wash.
Shriber, W. H., Deschutes Power & Light Co., Bend, Ore.
Siegel, M. C., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Signor, C. B., Cia. Cubana de Electricidad, Inc., Santiago, Cuba
Simokaitis, B., Simonds Saw & Steel Co., Chicago, Ill.
Sneed, D. H., American Tel. & Tel. Co., Atlanta, Ga.
Snyder, E. H., Public Service Electric & Gas Co., Newark, N. J.
Sorteberg, J., 182 Cumberland St., Brooklyn, N. Y.
Spencer, T. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Sperr, W. H., Brooklyn Edison Co., Brooklyn, N. Y.
Spieth, J. T., Florida Power & Light Co., Lakeland, Fla.
Steede, J. H., British Columbia Railway Co., Vancouver, B. C.
Strandberg, H. V., City of Seattle Engineering Dept., Seattle, Wash.
Strieder, H. P., Laclede Gas Light Co., St. Louis, Mo.
Sumner, J. R., Rochester Gas & Electric Corp., Rochester, N. Y.
Sutherland, D. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Swales, J. K., United Power & Light Corp., Hutchinson, Kansas
Swecker, O. E., Chesapeake & Potomac Tel. Co., Washington, D. C.
Sweinhart, E. F., Pacific Door & Sash Co., Los Angeles, Calif.
Taft, G. R., General Electric Co., Schenectady, N. Y.
Tames, J. A., Canadian Westinghouse Co., Ltd., Hamilton, Ont., Can.
Taylor, W. F., Allis-Chalmers Mfg. Co., West Allis, Wis.
Teare, N. A., Montreal Light, Heat & Power Cons., Montreal, P. Q., Can.
Teevan, G. B., (Member), Brooklyn Edison Co., Brooklyn, N. Y.
Terrance, E. H., The Detroit Edison Co., Detroit, Mich.
Terry, G. S., Stone & Webster, Boston, Mass.
Terry, I. A., General Electric Co., Schenectady, N. Y.
Thomas, C. U., Duquesne Light Co., Pittsburgh, Pa.
Thomas, R. P., Wittenberg College, Springfield, Ohio
Thornton, H. P., Postal Telegraph-Cable Co., Atlanta, Ga.
Tobias, F. J., (Member), Marf Machine & Die Casting Co., Brooklyn, N. Y.
Trimble, W. E., (Member), Toledo Edison Co., Toledo, Ohio
Tung, C. T., General Electric Co., Schenectady, N. Y.
Turner, E. A., General Electric Co., Schenectady, N. Y.
Underwood, J. C., Georgia Railway & Power Co., Atlanta, Ga.
Van Brunt, LeR. C., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Vendley, C. E., Southern California Edison Co., Los Angeles, Calif.
Voelker, F., Jr., Bell Telephone Laboratories, Inc., New York, N. Y.
Walker, T. S., Red River Lumber Co., Westwood, Calif.
Wall, W. I., Sunlike Illuminating Co., New York, N. Y.
Wahlgren, R. S., Gardner Electric Transformer Co., Emeryville, Calif.
Walther, L., 142 St. Pauls Place, Brooklyn, N. Y.
Warner, S. A., Brooklyn Edison Co., Brooklyn, N. Y.
Weaver, G. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Welsh, W. J., Puget Sound Power & Light Co., Tacoma, Wash.
Wharen, C. G., The Bell Telephone Co. of Pa., Wilkes-Barre, Pa.
Willever, H. C., Edison Portland Cement Co., Stewartsville, N. J.
Williams, L. T., Southwestern Gas & Electric Co., Shreveport, La.
Williford, O. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Wilmot, F. E., Southwestern Bell Telephone Co., Pittsburgh, Pa.
Withrow, E. L., Western Electric Co., Inc., New York, N. Y.
Wolcot, B., Kansas City TelephoneCo., Kansas City, Mo.
Wolfe, K. M., Monongahela, W. Penn Public Service Co., Rivesville, West Va.
Wollaston, F. O., Commonwealth Edison Co., Chicago, Ill.
Woodman, C. M., Southwestern Bell Telephone Co., Ft. Worth, Texas
Woodrow, C. A., General Electric Co., Schenectady, N. Y.
Woodruff, R. T., Hartford Steam Boiler Insp. & Ins. Co., Memphis, Tenn.
Woolf, E. L., Western Electric Co., New York, N. Y.
Worden, B. L., (Member), The Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Yerger, L. K., Buffalo General Electric Co., Buffalo, N. Y.
Zoller, J., Bell Telephone Laboratories, Inc., New York, N. Y.
Total 302

Foreign

Cooper, J. R., Metropolitan Water Supply & Sewage Board, Brisbane, Queensland, Aust.
Davies, W. A. H., Newcastle City Council, Newcastle, N. S. W., Aust.
Kameyama, G. J., Sumitomo Goshikaisha, Tokio, Japan
Kazama, I., Mitsubishi Electrical Engineering Co., Wadamisaki, Kobe, Japan
Khan, Z. A., Punjab Hydro-Electric Scheme, The Fort, Lahore, India
Leontiew, M. M., "Artemstroy"—District Power Station, Cancasus, U. S. S. R., Russia
Nanjundiah, R. A., Tata's Cement Co., Ltd., Shahabad, Deccan, India
Spry, P., Public Works Dept., Christchurch, N. Z.
Thick, R. W., The Lahore Electric Supply Co., Ltd., Lahore, Punjab, India
Total 9.

STUDENTS ENROLLED

Allen, Whiteman E., Northeastern Univ.
Anderson, Leslie J., Armour Inst. of Tech.
Anderson, Phillip, Univ. of Oklahoma
Athens, Edwin P., Louisiana State University
Augustine, Austin, Armour Inst. of Tech.
Augustine, Charles J., Yale University
Baker, George K., University of Denver
Baker, Paul K., Municipal Univ. of Akron
Ballinger, Victor H., The Municipal Univ. of Akron
Barnett, Daniel J., Worcester Polytechnic Inst.
Barrette, Cecil E., So. Dak. State College of A. & M. Arts
Bartholomew, Davis, University of Utah
Baumel, Ervin, Armour Inst. of Tech.
Baumgartner, A. B., University of Colorado
Bayless, Virgil K., Columbia Univ.
Beedle, Robert H., Northeastern Univ.
Bellamy, Phillip, Northeastern Univ.
Bierman, Philip W., Municipal Univ. of Akron
Blair, Charles E., Armour Inst. of Tech.
Blessington, G. L., Louisiana State University
Bliven, Richard E., Worcester Polytechnic Institute
Bond, A. Gordon, Marquette Univ.
Brewer, Rawlings, Jr., Washington Univ.
Brown, Wm. Joseph, Yale University
Brueggeman, William C., Univ. of Washington
Buffington, Gerald E., Municipal Univ. of Akron
Buhler, John S., Mass. Inst. of Technology
Burgess, Omar A., Pennsylvania State College
Burghoff, Henry L., Yale Univ.
Burkholder, Glenn E., Municipal Univ. of Akron
Burns, Louie M., Cornell Univ.
Cahill, Edward C., Engg. School of Milwaukee
Campbell, John C., Univ. of Cincinnati
Carneiro, Manuel S., Columbia University
Carr, Robert W., Mass. Inst. of Technology
Case, Byron A., Univ. of Washington
Christensen, Paul, University of Nebraska
Closson, Luke E., University of Maine
Cohn, Ralph I., Washington Univ.
Cole, Russell W., University of Utah
Dahlgren, Harold T., Armour Inst. of Tech.
Davis, Leland L., University of Illinois
Delagrange, Carl R., The Municipal Univ. of Akron
DeWitt, Milton M., Univ. of Oklahoma
Dickinson, Theodore M., Cornell Univ.
Dill, John, Kansas State Agr. College
Diwan, Jetha N., Mass. Inst. of Tech.
Doty, Ormond C., Oregon Agricultural College
Doubt, Robert D., Armour Inst. of Tech.
Dowling, Charles B., Jr., Clemson Agricultural College
Dulaney, Lynn S., Ohio State Univ.

Dungan, Theodore C., Ohio State Univ.
Dunn, Allen W., Calif. Inst. of Tech.
Dutton, Dean L., Kansas State Agr. College
Eaton, Thomas T., Univ. of Colorado
Ebner, Raymond J., Ohio State Univ.
Eder, Fred M., Iowa State College
Elliott, J. Opie, Univ. of Cincinnati
Ericsson, LeRoy J., Armour Inst. of Tech.
Everly, Arthur H., Armour Inst. of Tech.
Fenner, D. L., Rose Polytechnic Institute
Ferris, Bernhardt L., Univ. of Florida
Filcoff, George E., Washington Univ.
Foulds, Blair, Yale University
Frank, James, Jr., Yale University
Frank, Lester W., Worcester Polytechnic Institute
Friedman, Abraham S., Brown University
Fritschel, Erich P., Iowa State College
Fruehauf, Milton C., Case School of Applied Science
Fuller, Arthur C., Mass. Inst. of Technology
Furth, Ernest L., Washington University
Galeota, Joseph, Mass. Inst. of Tech.
Gammell, John, Univ. of Washington
Gangadharan, Gogulapati, University of Iowa
Gardner, David Z., Jr., Calif. Inst. of Tech.
Gibbs, Fred P., Univ. of Colorado
Gindele, Donald F., Univ. of Cincinnati
Gramer, Everett E., Armour Inst. of Tech.
Greenberg, Leo C., Harvard Univ.
Greenwald, Russell R., Municipal Univ. of Akron
Guilfoyle, Joseph, University of Maine
Harmon, J. S., Univ. of Oklahoma
Hartman, Edward R., Municipal Univ. of Akron
Hassler, Earl L., Univ. of Oklahoma
Hathaway, Donald L., Univ. of Colorado
Hawley, Alton W., Yale University
Head, James W., University of Virginia
Hewett, John B., Univ. of Oklahoma
Hickson, William A., Louisiana State University
Hinck, Ernest C., Jr., Mass. Inst. of Tech.
Hoag, Morris L., University of Utah
Hoehn, William E., Case School of Applied Science
Holt, George W., Oklahoma A. & M. College
Honey, William V., University of Utah
Hoover, Vaino A., Calif. Inst. of Tech.
Huddy, Franklin S., Brown University
Huntington, George R., University of Utah
Inglis, William G., Univ. of Oklahoma
Isler, Walter H., Univ. of Cincinnati
Johnson, Milton L., Kansas State Agr. College
Jones, Maurice A., Clemson Agricultural College
Joslin, Richard E., Ohio University
Kaiser, G. Elwood, Univ. of Oklahoma
Katzman, Samuel, University of Denver
Keevil, Henry W., University of Illinois
Kempster, Ernest B., Jr., Washington Univ.
Keneipp, Harold E., University of Ill.
Kenyon, Walter B., Cornell Univ.
Kepner, Walter William, Pennsylvania State College
Keune, Ernst, Univ. of Cincinnati
Kight, Rochell E., Univ. of Oklahoma
Kingsbury, Claude R., Ohio State Univ.
Koyama, Kinji, Mass. Inst. of Technology
Kozloff, Vladimir S., University of Denver
Labonte, Milton, Worcester Polytechnic Institute
Land, Robert, University of Denver
Larson, Harold E., Armour Inst. of Tech.
Lawrence, Walter L., Columbia Univ.
Lear, C. Merritt, University of No. Carolina
Leimer, Harold C., University of Arkansas
Lewis, Rollin C. W., Yale University
Lockhart, Jesse E., Univ. of Oklahoma
Loomis, George N., Yale University
Lovelace, Clyde, Columbia Univ.
Lundell, Arthur E., Engg. School of Milwaukee
Mallett. Walter R., Yale University
Maul, Charles R., University of Colorado
McClarren, Ralph H., Univ. of Washington
McCollum, Thelbert A., University of Oklahoma
McConkey, John R., University of Tennessee
McCoppin, Everett R., Ohio Univ.
McDermott, Byron, Univ. of Oklahoma
McGregor, Donald R., Yale University
McKinley, W. Ward, Ohio University
McNeil, Buel, Cornell Univ.
Menge, Clarence H., Armour Inst. of Tech.
Mighell, Richard H., University of Denver
Morrison, George W., University of Maryland
Muchnic, George, Mass. Inst. of Technology
Munson, Earl A., State College of Washington
Nelson, Harold E., Armour Inst. of Tech.
Niebruegge, Walter F., Engg. School of Milwaukee
Norell, Elmer G., Univ. of Cincinnati
Norris, J. R., Univ. of Oklahoma
O'Bryan, Leo F., Louisiana State University
Olmsted, Leonard M., Worcester Polytechnic Institute
Olson, Harold E., University of Denver
Otto, Roy S., Engineering School of Milwaukee
Ozment, Kenneth J., Louisiana State University
Pearson, Donald S., Case School of Applied Science
Perry, Middleton L., Jr., Mass. Inst. of Tech.
Pierce, Stevie F., Louisiana State University
Pomeroy, Frederick C., Worcester Polytechnic Institute
Potter, Keith W., University of Denver
Reine, John, Princeton Univ.
Richardson, Earl L., Northeastern University
Righter, Walter H., Calif. Inst. of Tech.
Ross, Donald H., Bucknell University
Rugg, Philip N., Mass. Inst. of Tech.
Salminen, Arno G., Harvard University
Sandberg, Carl R., Iowa State College
Schafer, J. Edward, Municipal Univ. of Akron
Schor, Ferdinand W., Armour Inst. of Tech.
Schwarz, Harvey F., Washington Univ.
Secor, Clark K., Brooklyn Polytechnic Institute
Sherman, Wilson R., Northeastern Univ.
Shuster, John D., Calif. Inst. of Tech.
Smith, George H., University of Florida
Smith, O. Telfair, Jr., Rensselaer Poly. Institute
Spenko, Julius F., Case School of Applied Science
Statuta, Joseph M., The Municipal Univ. of Akron
Stay, Charles, Lehigh Univ.
Taylor, Robert Z., Univ. of Oklahoma
Taylor, Thomas A., Harvard University
Tierney, Frank P., Jr., Univ. of Colorado
Tinley, Charles D., Municipal Univ. of Akron
Tinling, Hugh B., State College of Washington
Tiongson, Juan L., Cornell Univ.
Tryon, Ralph C., Municipal Univ. of Akron
Tschantz, John L., Iowa State College
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West, Glenn E., Montana State College
Westby, George N., Univ. of Washington
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Wilson, James U., Clemson Agricultural College
Wilson, Taylor F., Lehigh Univ.
Windham, Joseph P., University of Florida
Wittgren, Charles, Jr., Armour Inst. of Tech.
Wray, F. Ellis, Univ. of Florida
Wright, Sim C., Univ. of Oklahoma
Yogerst, Walter M., Marquette Univ.
Total 194.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.
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MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL ENGINEER, with several years' active experience in the design and application of universal motors. Apply by letter stating fully experience, education, age, and whether or not employed at present time. Location, Pennsylvania. X-1304-C.

GRADUATE, young, electrical or electrochemical engineer, for manufacturer of storage batteries and radio appliances. Must be interested in battery production and development. Apply by letter. Location, Wisconsin. X-1154-R-124-C.

GRADUATE MECHANICAL ENGINEER. Must be familiar with the theories and experienced in the technical design of heat exchanges. Must also have practical experience in combustion and power station operation. Must be able to direct an engineering organization. Apply by letter. Location, New York City. X-1349.

ENGINEER, experienced in field work in connection with the natural gas business. Should

be thoroughly experienced in the production of natural gas and capable of assuming the duties of an executive. Salary $250-$400 a month, to start. Apply by letter. Location, Pennsylvania. X-1097-C.

ELECTRICAL ENGINEER, qualified as chief of a manufacturing company, whose product includes practically all types of fractional horsepower electric motors fans. Must be able to conduct research work in connection with such motors, and capable of organizing a research department. Location, Middle West. X-1515-C.

MEN AVAILABLE

ELECTRICAL ENGINEER, 28, Englishman, twelve months in United States, desires opportunity where the following training and experience could be utilized. Eleven years technical and practical electrical engineering covering iron and steel works electrical application, installation and maintenance, central stations, and plant erection for large manufacturing company in England. Oil fields electrification in India, and public utilities in United States. Extensively traveled. Would undertake foreign representation, or sales, or erection. or inspection of electrical plant and machinery, C-625.

ELECTRICAL ENGINEER AND JOURNALIST, 23, technical graduate with several years' successful newspaper and literary experience, desires position on publicity staff of large manufacturer or public utility. Can furnish excellent reference from prominent editors and engineers. C-2189.

ELECTRICAL ENGINEER, with executive ability, competent in electrical and mechanical design and manufacture of electrical machines and apparatus, familiar with layout and operation of power and substations, able to systematically carry on scientific and practical research work in electrical, mechanical and physical problems, with very good experience in automotive electric traction. Speaks German and French. Wishes to make new connection. C-693.

SALES ENGINEER, 38, married, eleven years' experience with well known elevator concern in construction, service and sales departments in United States, Panama, and Great Britain. Familiar with all departments of the elevator industry. Preference Pacific Coast, but will go anywhere. Available immediately. C-1567.

ENGINEER, 29, graduate of well known technical institution, class of 1922, with S. B. in electrical engineering, desires change to development work in communications field. Experienced operation and maintenance of high power radio transmitters, medium power tube transmitters, development work short wave transmitters, also some experience radio receiving sets. At present employed. Location desired, Middlewest or East. B-8831.

ELECTRICAL-MECHANICAL ENGINEER, technical graduate Wisconsin University, twenty years' practical experience; seven years draftsman, two and one half years manufacturing apprentice, four years canal lock, substation and power plant operating, two years valuation and cost engineering, one year selling engineering equipment, three years steam and gas theory and testing, etc. Prefers production and selling lines. A-3651.

ELECTRICAL ENGINEER, nineteen years' experience in design, construction, operation and management. Public utility and consulting engineering work. Transmission lines, substations, railway equipment and power plants containing units up to 30,000 K. W. Now in charge of design for a large public utility company. Desires position of responsibility in Chicago or Middlewest. Technical education. Age 39, married. C-2217.

JUNIOR ENGINEER, 1923 graduate, one year's experience as illuminating engineer, two years' experience at telephone cable and transmission engineering and inspecting, one year's experience transformer engineering. Desires position in construction or power installation work. Location, East. Available at any time. C-2223.

EDITOR, 31, married, university journalistic education, and thirteen years' practical experience as associate editor, co-publisher-editor, and managing editor of radio and technical publications, including trade paper. Editor and author of numerous technical papers, magazine articles and books. Available within three weeks after appointment. Location, New York. C-829.

RECENT GRADUATE IN ELECTRICAL ENGINEERING, married, 24, desires position with a large radio concern in California. Had two years' experience installing central office telephone equipment. C-1813-8-C-3.

ELECTRICAL-MECHANICAL ENGINEER, graduated from the Royal Turin's Polytechnic (Italy), 31, single, four years in United States. Inventive ability, several patents, design electrical machines experience. At present designing engineer in radio engineering department of leading company. Willing to travel, or go abroad also. Speaks English, French, Italian. Desires to connect with reliable concern. B-7208.

ITALIAN TELEPHONE ENGINEER, fourteen years' experience, graduate in E. E., speaks English, French, German, wishes connection with American telephone manufacturer or financial firm interested in telephone development in Italy. First class references as consulting engineer. C-2232.

ELECTRICAL ENGINEER, East Indian college graduate '25, year and a half General Electric test experience, seeks connection with firm dealing in foreign countries, preferably India. Best references. C-2231.

GRADUATE IN ELECTRICAL ENGINEERING, desires a position with a future. Experienced in radio transmission and has had eight years' amateur experimental radio work. Also experienced in drafting, and three years' experience in civil engineering. Location, Philadelphia, or vicinity. Available in two weeks. C-2129.

ELECTRICAL ENGINEER, 41, married, with considerable experience in development and research work of intricate electro-mechanical propositions such as automatic train control, sound direction finder, automatic telephones, etc. M. E. and E. E. degrees. Available two weeks. Location desired, New York City. A-165.

TECHNICAL GRADUATE, 1922, 24, married, desires a position as meterman or general tester with a public utility. Capable of taking charge of meter department. Experience consists of three years meter work, one year electrical construction in steel mill. Available fifteen days. B-7464.

POWER AND MAINTENANCE MAN, with experience in steel mill, hardware manufacture, automobile plant and oil refinery, desires position as superintendent of power and maintenance. A-3854.

GRADUATE ELECTRICAL ENGINEER, seven years' experience in the engineering and construction of aerial and underground distribution, transmission and street lighting systems. Desires position with firm or public utility engaged in transmission or station construction projects. Employed at present. Location immaterial. Available on three weeks' notice. B-9408.

ELECTRICAL ENGINEER, B. Sc. Eng. London 1920, age 32, six years' experience with large electrical engineering firm in England, five years European War service, desires a post in constructive work of any kind as an electrical engineer. Location, any part of the world. Unmarried. Available in one month. C-2248.

GRADUATE MECHANICAL AND ELECTRICAL ENGINEER, available at once for position in New York City. Design, construction, operation or valuation requiring business judgment, common sense and twenty years' engineering experience. Native born white American, residing in suburban section of New York City since 1912. C-2296.

ELECTRICAL AND MECHANICAL ENGINEER, several years' experience with large electrical manufacturer, desires responsible position as manufacturing engineer, research or process engineer. B-147.

LICENSED PROFESSIONAL ENGINEER, M. I. T. education, with fourteen years' engineering and construction experience in the design of power station, substations, power and lighting of industrial buildings, appraisal of electric properties, desires a new connection with an engineering organization doing big things, preferably in New York City. B-5393.

ELECTRICAL AND MECHANICAL ENGINEER, technical graduate, G. E. test man, twenty years' experience in handling Union and non-Union labor in power house work and the mechanical and electrical end of mining and treating gold, silver, lead and zinc ores and coal in the States, Alaska and Mexico. Speaks Spanish. Location immaterial. B-8872.

ELECTRICAL ENGINEER, 27, who can add common sense to engineering training, desires responsible position with concern manufacturing electrical apparatus, preferably in New York City. Available on one month's notice. Salary $250 a month. B-7270.

RADIO ENGINEER, college graduate, ten years' broad experience, including development of broadcast transmitting equipment and modern commercial broadcast receivers. Thoroughly familiar with modern practises in the art. At present employed, but desires change. C-2273.

TECHNICAL GRADUATE (German engineering school), age 27, American citizen. Knowledge of radio code, typewriting, German correspondence. Three years United States radio sea service, three years' clerical factory experience. Familiar with conditions in Central Europe. Desires engineering or drafting position in New York or vicinity (Northern New Jersey). Will also accept foreign assignment (Central Europe). Sample work and details on request. References here and abroad. Available after January 15th. C-2269.

SWITCHBOARD ENGINEER, due to miscarriage of plans for advancement by present employer, must have position. Has designed and supervised switching equipment, particularly automatic stations, located in all parts of United States. Cornell M. E. E. E., age 37. Present salary $3300. Open to offer. C-2272.

COLLEGE GRADUATE, E. E., age 25, over two and one-half years' combined Westinghouse graduate student course and test experience, desires position with large public utility, or with manufacturing concern. Prefers theoretical phrases of engineering rather than mechanical details. Theory in experimental or development work would appeal. Location in Philadelphia or immediate vicinity. Available in about three weeks. C-2280.

GRADUATE ELECTRICAL ENGINEER, single, good appearance and personality. Six years' general engineering experience, G. E. test, testing automatic telephone equipment, supervision electrical installations, indoor, outdoor substation design. Illumination. Available now. Location preferred, New York City. C-2268.

ELECTRICAL ENGINEER, graduate, age 31, married, wide experience on electrical layouts and designing as draftsman for about ten years. Field experience on electrical construction two years. Resourceful and original. Assoc. Member A. I. E. E., Member Eastern Association of Electrical Inspectors. B-5518.

COMMERCIAL ENGINEER, graduate 1908, thoroughly experienced in power sales for large industrial operations, invites correspondence with holding company who require executive to organize actively department for negotiations of larger power contracts and to build up power load. A successful record and highest type of reference as to character, ability of accomplishment and personality offered. B-4221.

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(Terms expire July 31, 1928)	(Terms expire July 31, 1930)
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John W. Lieb, 1904-5.	Harris J. Ryan, 1923-4.
*Schuyler Skaats Wheeler, 1905-6.	Farley Osgood, 1924-25.
*Samuel Sheldon, 1906-7.	M. I. Pupin, 1925-26.

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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Transformers.—Bulletin 136, 4 pp., describes Wagner transformer tap changers. Wagner Electric Corporation, St. Louis, Mo.

Vitrohm Resistors for Radio.—Bulletin 507, 8 pp. Describes Ward Leonard Vitrohm resistors, with specifications, for all radio circuits. Ward Leonard Electric Company, Mount Vernon, N. Y.

Trickle Battery Charging.—Bulletin, 20 pp. "Balkite Trickle Charging," describes the Balkite Trickle Charging System and its application to various electrical devices. Fansteel Products Company, Inc., North Chicago, Ill.

Electric Clocks.—Bulletin, 20 pp. Describes Sangamo electrically wound clocks, for household and other uses, on alternating-current circuits. The clocks are supplied with an extension cord and attachment plug, permitting easy connection to any convenient outlet or lamp socket. Sangamo Electric Company, Springfield, Ill.

D-C. Control System.—Bulletin GEA-451, 12 pp. Describes mill type control systems for direct-current motors. Originally designed for use in connection with motors driving steel mill auxiliaries, the system can easily be modified to meet special requirements, and fills a pressing need for the control of direct-current motors in any service where it is necessary to start the motor under high or variable loads, and run it under light load conditions, or where rapid and frequent reversals and stoppages form part of the duty. General Electric Co., Schenectady, N. Y.

NOTES OF THE INDUSTRY

Harry M. Giles Dies.—Harry M. Giles, General Superintendent of the South Philadelphia plant, Westinghouse Electric & Mfg. Co., and well known in the marine and power industries, died on December 14, at Atlantic City. Mr. Giles, who was 57, had been associated with the Westinghouse Company since 1900.

The Electric Controller and Manufacturing Company, Cleveland, Ohio, announces the appointment of Farr Electric Service, Inc., 228 W. South Temple, Salt Lake City, Utah, as its representative; also, the removal of the Toronto office from The Traders Bank Building to 415 Metropolitan Building, Toronto, Ontario.

American Brown Boveri Appointments.—The American Brown Boveri Electric Corporation has made the following additions to its Camden, N. J. staff: J. M. Van Nieukerken, as Railroad Project Engineer; Wilfred S. Lowry has been assigned to the Blower Division; Harold D. Gregory, Patent Department; Raymond Lewis Stanton, Application Engineer in the Blower Section; Frank T. Horan, Oil Circuit-Breakers; Herbert C. Mode, Railroad Division.

Stone & Webster and Blodget, Inc., Organized.—Stone & Webster, Inc., and Blodget & Co., announce the formation of a new company under the name of Stone & Webster and Blodget, Inc. The company began operations on January 1, with an authorized capital of $10,000,000. The new corporation is a combination of the securities department of Stone & Webster, Inc., and the old investment house of Blodget & Co. The engineering and construction, management, and investigating departments of Stone & Webster, Inc., are not included and will not be affected by the combination. Bayard F. Pope, now a partner of Blodget & Co., will be president of the new company. Other officers and the directors will be drawn from both the participating companies. The head offices will be at 120 Broadway, New York.

Turbine Operating at 1200 Pounds Pressure.—The Milwaukee Electric Railway and Light Company has started operation of a steam turbine-generator which uses steam at a pressure of 1200 pounds, between three and four times the average pressure of today's generating plants and, with one exception, double the pressure in use in any station. This exception is the 3000-kilowatt turbine-generator in the Edgar station of the Edison Electric Illuminating Company of Boston, which also operates at 1200 pounds pressure. The Milwaukee machine sets a record however, in that it has a capacity of 7000 kilowatts, more than twice that of the Edison unit. Both are of General Electric design and manufacture.

New Rotating Cam Limit Switch.—The Electric Controller & Manufacturing Company of Cleveland, Ohio, has developed a new rotating cam limit switch to be used with magnetic controllers for the automatic control of machines having such fixed sequence of operation as slowing down, stopping and reversing. This switch is totally enclosed, is equipped with tapered roller bearings and is designed to carry six sets of contacts. The cams which operate the opening and closing of the contacts are each adjusted independently of the others and can be fixed at an infinite number of positions, giving extreme flexibility to the machine with which it is used.

Colt's Fire Arms Absorbs Johns-Pratt.—Announcement has been made that the Johns-Pratt Company has been totally absorbed by the Colt's Patent Fire Arms Manufacturing Company, both of Hartford, Conn. Although control of the Johns-Pratt Company has for the past few years rested with the Colt's Company, its activities were carried on as a division of the parent organization.

The Johns-Pratt Company, for years one of the foremost manufacturers of sheet packing, has more recently come prominently before the electrical industry as a developer of electrical protective devices, such as meter service switches, fuses, service boxes, and high-voltage underground equipment. Colt's Patent Fire Arms Mfg. Company was established in Hartford in 1836, and has grown until its plants now cover 21 acres of ground. With enlarged facilities for production and unlimited financial resources, it is planned to further develop and extend the electrical lines pioneered by the former Johns-Pratt Company.

More Than a Half Billion Lamps in 1926.—Well over a half billion incandescent lamps, including 315 million "large" lamps and about 205 million miniature lamps, were sold in the United States in 1926. These quantities represent the greatest annual increase in the history of the lamp industry during its almost half century of existence, according to John Liston of the General Electric Company in his annual review of the electrical industry. The increase over 1925 sales amounted to 12½ per cent in the case of the large lamps, and five per cent for the miniature lamps, for automobiles, flashlights, etc. In addition, the present prices of incandescent lamps are the lowest in the history of the industry, the list prices of the large Mazda lamps having been reduced on an average of 6½ per cent during the past year.

Recent Westinghouse Orders.—Twenty-eight truck-type panels for use in connection with the new unit No. 5 of the Crawford Avenue Station of the Commonwealth Edison Company were recently ordered from the Westinghouse Electric & Manufacturing Company.

Equipment for the second section of St. Louis' street-lighting program will be furnished by the Westinghouse Company. The contract, awarded to the contractor December 17, involves $650,000 and calls for the installation of nearly 3300 lighting units and accessory equipment within the next four months. The award came the day following the establishment of service on the first of nearly 10,000 units, also supplied by the Westinghouse Company.

The Ohio Power Company of Canton, Ohio, has ordered from the Westinghouse Company twenty-eight, type CM, automatic network units to take care of the increasing load in the downtown section.